SCIENCE APPLICATIONS, INC.

DISPOSAL AREA MONITORING SYSTEM

ANNUAL REPORT

1980

VOLUME I

PHYSICAL MEASUREMENTS

DAMOS CONTRIBUTION # 17

Edited By:

Robert W. Morton Carolyn A. Karp

Submitted to:

New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Submitted by:

Science Applications Inc.
Ocean Science & Technology Division
202 Thames Street
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1.0 INTRODUCTION

1.0 INTRODUCTION

1.1 Background

The Disposal Area Monitoring System (DAMOS) has been a continuing program for management and monitoring of dredge material disposal in the New England coastal marine environment. During 1978 and 1979, the New England Division of the U.S. Army Corps of Engineers sponsored symposiums to report results of the monitoring effort. During 1980, however, new data were presented at the NOAA sponsored 2nd Annual International Ocean Disposal Symposium held in Woods Hole, MA, and therefore, no Corps sponsored DAMOS symposium was held. Consequently, unlike earlier DAMOS Annual Reports, this document is not a duplication of previously presented papers, but rather a summary of the work accomplished since the symposium conducted in March 1979.

The period covered by this report marked a transition stage in several areas of the DAMOS program. After two years of background study, all of the 12 disposal sites considered under this program were well characterized in terms of topography, current regime, sediment properties and benthic populations. Consequently, with the advent of major disposal operations at the Central Long Island Sound and Portland sites and continued disposal at the New London site, a decision was made to concentrate funding and logistic resources in these areas and to reduce or eliminate the monitoring effort at the inactive areas.

This decision tended to place the DAMOS program in a more active role in the monitoring and management activities associated with the disposal operation itself and, for a period of time, reduced the efforts related to long term monitoring, theoretical studies and instrumentation development. Consequently, the studies related to resuspension of disposed dredged material were reduced through elimination of the BOLT and UDSS development programs, and studies evaluating the fisheries in the regions of dredging ctivity were terminated. Furthermore, the measurements of heavy metal uptake by caged mussels were concentrated at the three active sites through more frequent sampling while observations were stopped at the inactive sites. Sampling procedures for both benthic population and sediment chemistry were also altered to provide more replicates and more detailed sampling plans in the areas immediately adjacent to the disposal operations. Finally, the bathymetric surveys were reduced in overall area covered, but increased significantly in terms of resolution through precise replication of 25m lane spacing grids.

In addition to these changes in approach to the program, several delays and interruptions to the project were caused by problems associated with the Naval Underwater Systems Center withdrawing as an active participant in DAMOS, with funding availability, and with contracting key personnel through Science Applications, Inc. Most of these problems have since been resolved, and continuation of the DAMOS program as a viable approach to monitoring and managing the disposal of dredged material in New England seems assured.

The following sections of this report will provide detailed information on the results of measurements taken during 1980. Some additional data are also provided from surveys conducted during previous years, but unreported due to more complicated analysis procedures. A chronological summary of the cruises conducted during 1980 and the measurements made at each site visited are presented in Table 1.1-1.

1.2 Management Procedures for Disposal of Dredged Material

The reorientation of DAMOS toward monitoring of specific disposal operations has resulted in the development of a management approach that should greatly decrease the chances of adverse environmental impacts caused by such disposal in the marine environment. These management procedures are based primarily on the chemical composition and cohesive nature of most New England dredged material, the appropriate location of disposal sites in terms of natural sediment parameters and turbulent energy regimes and the careful placement of the dredged material at those sites in such a manner as to reduce the potential for exposure of contaminated material either to the water column or the benthic population. All of these procedures have been worked out in conjunction with various state and federal agencies; and prior to any disposal operation, a management plan consistent with previous disposal operations at the site is prepared. This plan always includes provisions for monitoring always after, and frequently during disposal.

A key to comprehensive management of dredged material disposal is the establishment of a small number of regional disposal sites. With this approach, monitoring of the results of previous disposal operations can contribute significantly toward

TABLE 1.1-1
Summary of DAMOS measurements conducted during 1980

DATE	LOCATION	EVENT
3/21/80	NLON	Loran-C calibration Bathymetric survey
3/25/80	NLON	Benthic & sediment samples Diver observations
3/26/80	NLON	Additional survey Deploy disposal buoy Complete sampling
4/1/80	CLIS	Norwalk baseline survey Deploy Norwalk disposal buoy Baseline benthic & sediment samples Loran-C calibration STNH-S bathymetric survey
4/2/80	CLIS	STNH-N benthic samples STNH-N bathymetric survey Norwalk sediment chemistry
4/3/80	CLIS	Complete sampling Calibration check on Norwalk buoy
4/8/80	PORT.	Set lobster traps Bathymetric survey Benthic & sediment samples (ISE) Loran-C calibration Retrieve lobster traps Benthic grabs (ISE)
4/9/80	PORT.	Sediment chemistry samples
4/10/80	PORT.	Ready acoustic releasers Deploy mussel cage U/W TV stations CTD cast
4/24/80	CLIS	Deploy mussel cages at STNH-S, Norwalk, Ref. Site & STNH-N.
5/8/80	PORT.	Recover & deploy mussel cage Dive at Bulwark Shoals
5/15/80	WATCH HILL	Retrive disposal buoy from beach
5/16/80	NLON	Deploy disposal buoy
6/3/80	PORT	Deploy deeper trawl

		Change disposal buoy light Diver ops at Bulwark Shoal
6/10/80	NLON	Bathymetric survey
6/11/80	NLON	Remove disposal buoy
6/12/80	CLIS	Bathymetric surveys: STNH-S,STNH-N, Norwalk
6/19/80	CLIS	Removed New Haven buoy
6/26/80	PORT.	Hauled mussel trawl Diver operation Bulwark Shoal
6/30/80	PORT	Replace disposal buoy
8/18/80	PORT	Benthic & sediment chemistry samples
8/19/80	PORT	Bulwark Shoal mussel samples Disposal site mussel samples Grabs at Ref. site
8/21/80	PORT	Loran-C calibration survey
8/22/80	PORT	Loran-C calibration survey
8/25/80	PORT.	Obs. buoy position Side scan survey
8/26/80	PORT.	Diver observations Photo transect Sediment samples CTD cast Photo transect
8/28/80	NLON	Sediment samples Bathymetric survey CTD cast
9/3/80	CLIS	STNH-S, sediment samples STNH-N sediment samples
9/4/80	CLIS	CTD cast Norwalk Norwalk sediment samples
9/5/80	CLIS	STNH-S sediment samples Ref. sediment samples
9/19/80	PORT.	Mussel samples disposal site & Bulwark Shoal Ref Diver ops.
10/3/80	NLON	Loran-C calibration
10/6/80	NLON	Install NLON disposal buoy

10/21/80	PORT.	Mussel samples - disposal site & Bulwark Shoal ref. Diver ops.
12/6/80	WELLFLEET	Bathymetraic survey CTD cast
12/9/80	ISLE OF SHOALS	Sediment samples Current meter implant
12/10/80	PORT.	CTD cast Sediment samples
12/11/80	PORT.	CTD cast Sample mussel Bottom photography Sediment samples CTD cast Water samples
1/14/81	Isle of Shoals	Recover current meter
1/20/81	NLON	Bathymetric survey
1/21/81	NLON	Sediment samples
1/22/81	NLON	Water samples
1/23/81	NLON	CTD Cast
1/27/81	CLIS	CTD cast STNH-S V/W TV-photo transect Standard bathymetric surveys

predicting the effects of new disposal and the impacts of all disposal operations can be observed. If each new project were to have a separate designated disposal site, monitoring would soon be impossible due to cost and logistic limitations.

Proper management of disposal begins with a characterization of the sediments to be dredged, particularly relative to their potential toxicity. This is accomplished through several procedures such as bioassays, bulk chemical analyses, sediment classification schemes, etc. which allow the manager to decide first whether or not the material is suitable for open water disposal, and if so, how it should be placed at the disposal site.

Following this, if the management process specifies ocean disposal as the most appropriate procedure, selection of a disposal site is generally based on the distance to the nearest regiional dsposal area. These regional disposal areas have generally been established according to the following criteria:

- Previous disposal which indicates overall containment of dredged material
- Isolation from nearby shellfish areas or fisheries interests
- Lack of important habitat areas in the immediate vicintiy
- Natural sediment similar to that being dredged
- Low currents and wave energy regimes
- Low utilization of the area by other marine interests.

Within the selected regional disposal area, a specific dumping point will generally be specified. Recent applications of point dumping procedures, either through use of a taut wire moored disposal marker, or calibrated Loran-C navigation under computer control, have proven to be an important factor in successful management of dredging and disposal operations. The ability to restrict the disposal operation to a small area, in concert with the cohesive nature of most dredged material has resulted in the development of distinct, compact disposal mounds that drastically reduce the surface area of dredged material exposed to the surrounding environment.

Furthermore, these mounds can then be covered with cleaner material dredged either from the same project or from subsequent operations to further isolate the more toxic material from the sediment surface. This covering procedure is closely tied to the sediment classification schemes discussed above since the chemical and physical properties of the sediments will affect their placement on the disposal mound.

All of these disposal procedures are then closely monitored through physical, chemical and biological measurements. The results of these measurements to date indicate that the observed effects of disposal are restricted to the immediate area surrounding the disposal point and, once initial adjustments in the sediment surface occur, the dredged material remains stable. Furthermore, biological impacts beyond the margins of the site have to date been undetectable.

1.3 Application of DAMOS Management Procedures at the Central Long Island Sound Disposal Site

An example of the management procedures developed as a result of the DAMOS program occurred at the Central Long Island Sound Disposal site, where the New England Division of the U.S. Army Corps of Engineers has been conducting a carefully managed and monitored program of dredge material disposal during 1979 and 1980. This program has been concerned with the coverage or "capping" of contaminated material from Stamford Harbor with cleaner material from New Haven. This capping procedures resulted in a steep-sided, compact mound of spoil material (Figure 1.3-1) that was developed by point dumping of material at a taut-wire moored buoy. Consequently, when additional capping material was available for disposal, it was necessary to dump this material at some distance from the buoy to avoid excessive shoaling of the mound.

Two general areas for capping were identified: one, approximately 300 meters west of the buoy where some Stamford material was exposed, and second, around the southern margin of the spoil mound where additional material would increase the thickness of the cap. Since placement of a series of taut-wire buoys to control this disposal would be cost prohibitive, an alternate plan using computer enhanced Loran-C control was initiated to manage the disposal operation.

An additional benefit derived from the enhanced Loran-C approach to disposal is the ability to monitor and manage the dumping procedure. During this operation, Loran-C data were recorded at five (5) minute intervals during transit to the site, and more frequently, as specified during the dumping operation by the inspector.

1.3.1 Instrumentation

The navigation system installed aboard the tug ERNEST M was a prototype of a sophisticated microprocessor controlled navigation system under development by Scince Applications, Inc.

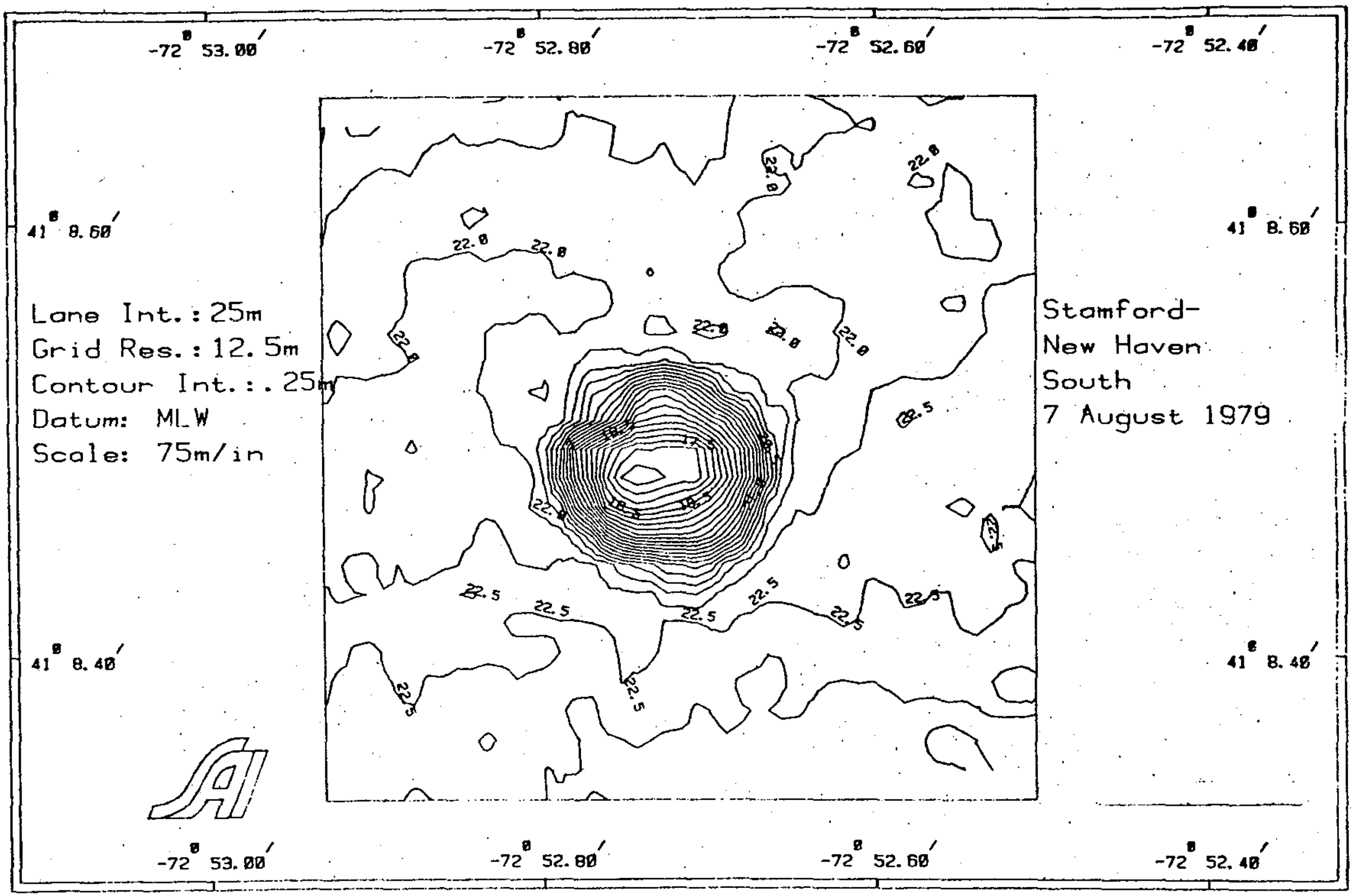

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in
Stamford-
New Haven
South
7 August 1979
22.0
22.5

Figure 1.3-1

This prototype system (Figure 1.3.1-1) consisted of an Apple II microcomputer equipped with a real time clock, a magnetic disk recording system and a video monitor. The computer was interfaced with a Northstar 6000 Loran-C receiver equipped with a navigation pack which provided serial data output through a Northstar 6700 interface unit. During operation, this Loran-C receiver provided the computer with data at a variable rate between 2 and 7 seconds. Newer versions of the interface are available, however, which can generate data at a constant two second repetition rate.

The Loran-C time delays after processing by the computer, were used to determine a series of navigatioon parameters including:

- Latitude and longitude coordinates
- Range and bearing to destination
- Course and speed made good

These paramters were then used to provide navigation information to the helmsman through the video display. In order to maintain simplicity on this prototype unit only one display was available as shown in Figure 1.3.1-2. The center of the large cross represents the destination or disposal point. The scale of distance between tick marks on the large cross varied automatically depending on distance to the point and was displayed in the upper left corner of the screen. A minimum of 10 meters/division was used as the tug and scow approached the disposal point. On all displays, the ship was designated with a small cross (+) and the ship's track was maintained as a series of sequential crosses indicated previous position.

Time of day, range and bearing to the disposal point and

SAI APPLE II NAVIGATIONAL SYSTEM

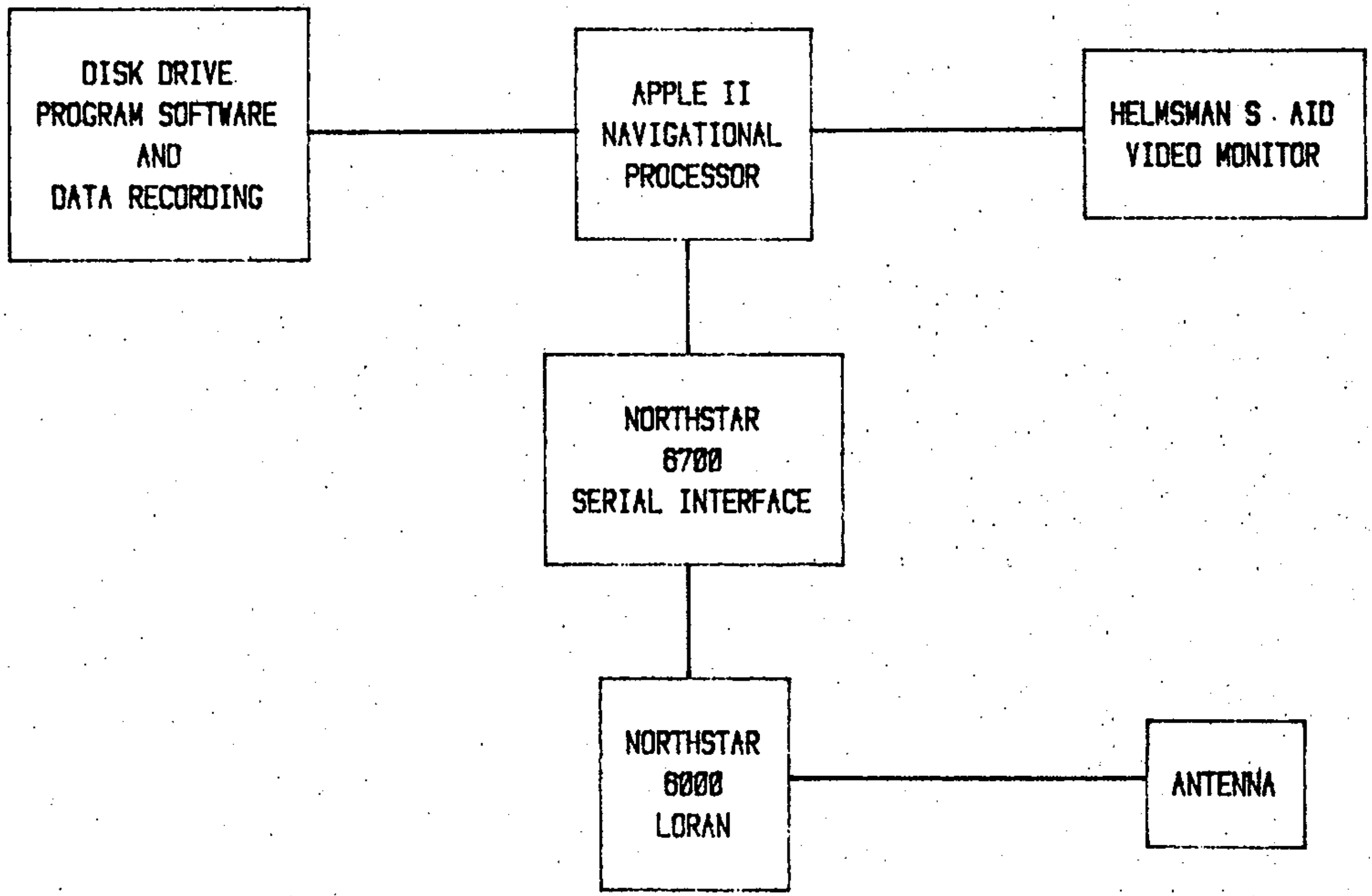
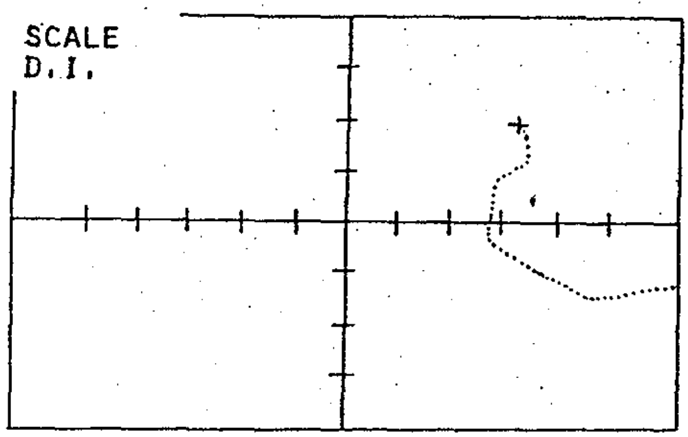


Figure 1.3.1-1



VIDEO DISPLAY

RANGE AND SCALE ARE IN METERS
BEARING IS MAGNETIC

Figure 1.3.1-2

course made good were displayed at the bottom of the video screen and updated with each new data set. The inherent variability of raw Loran-C data, requires the application of smoothing functions before the calculated parameters are displayed for use by the helmsman. These smoothing functions must be applied in a manner that does not degrade the overall calibrated accuracy of the Loran data.

In addition to the visual display of data, time of day and position information are recorded on mini-floppy disks to provide a capability for monitoring the disposal operation. Once the system is started, these data are recorded at 5 minute intervals. However, a special function key on the computer permits the disposal inspector to override the sequence and record the positions at the start and end times of (or any time during) disposal. This key also sets an indicator bit to designate the fix as a disposal location.

The software generated for this prototype system contains other features specifically oriented toward control of dredge material disposal, including:

- Special function keys to designate a number of disposal points, each defined prior to the operation and specified by a particular code.
- Special function key to reverse the start and end points thus providing navigation control back to the dredging site after disposal
- Special function key to record calibration data at the start of each disposal trip
- Special function key to set and maintain a specific scale on the video display.

In summary, the system used at the Central Long Island

Sound Site was a prototype unit developed to manage the disposal operation for a short period of time. Although the system proved adequate for this purpose, future units would be more compact, better packaged and more flexible in terms of video displays and data presentation.

1.3.2 Procedures

The value of a navigation system such as the unit described here depends to a large extent on the ability of ship personnel to utilize the data available. Consequently, the system must be easy to operate, must not interfere with normal ship procedures, must present the data in a clear and understandable manner, and must provide an efficient method for conducting the disposal operation without undue delay. The system described earlier was able to accomplish all of these requirements based on the following procedures.

Prior to installation of the system, calibration of Loran-C in the operating area was conducted by measuring the time delay readings at the disposal buoy and at a channel buoy (No. 7) at the entrance to New Haven Harbor. Using these data, the locations of specific disposal points were calculated in terms of Loran-C time delays relative to the disposal buoy. Another approach to calibration, where disposal buoys were not available utilized precision microwave navigation systems to provide absolute position versus Loran-C time delay values for a specific area. This procedure would, of course, be required only once; prior to the beginning of the disposal operation.

Calibration at the channel buoy is only required to insure that the Loran-C receiver has "locked on" to the correct pulse of the Loran signal and is in fact providing accurate position data. If the receiver is not tracking properly, errors will occur in multiples of 10 μsec in time delay, which represent significant changes in position. All Loran-C receivers have provisions for setting the readout to the correct value, therefore, a simple check of the Loran reading when passing the channel buoy will insure proper positioning. Once this has been completed, the computer will detect any loss of track and will insure that calibration has been maintained from the harbor to the disposal point.

After the tug has the loaded disposal scow alongside, the ship proceeds out of the channel. As the tug passes the designated calibration buoy, the inspector checks to insure that the Loran receiver is tracking correctly, either by reading the time delay values, or by pressing a special function key which compares the present reading with a preprogrammed value. If the Loran time delays are satisfactory, the tug proceeds to the disposal site, if not the receiver must be adjusted to provide the correct values.

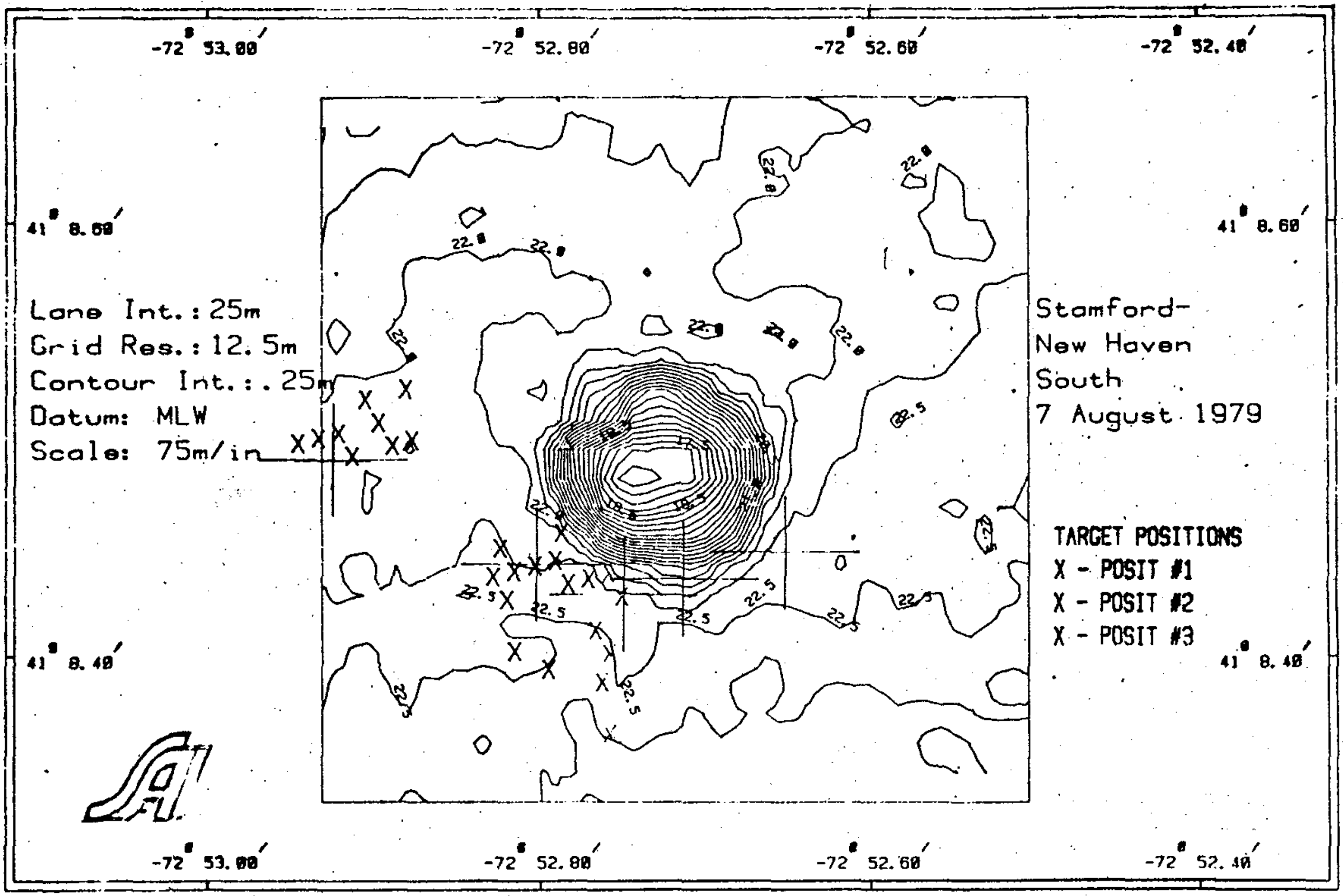
After leaving the harbor, the tug steers directly for the disposal site using the video display and the principle of constant bearing to approach the dumping point. To accomplish this, the helmsman simply steers to make the bearing to the point and the course made good equal (a right turn raises the course made good, a left turn lowers it). This procedure automatically corrects for tidal set, wind drift, compass error, etc. and insures that the point can be approached from any direction. As the tug approaches the disposal point the ship is slowed, and once the range to the disposal point is less than a specified distance (in this case, 20m), the scow is dumped. At the time of dumping, the inspector presses the special function key to record the location of disposal. This can be done more than once if disposal requires extended periods of time or if additional passes are necessary to dump all pockets in the scow.

After completion of the disposal operation, the special function key to reverse direction is pressed and the computer provides navigation control back to the calibration point at the harbor entrance. Periodically during the dredging and disposal operations, the disks will have to be changed as they are filled with data, however, this is an extremely simple matter requiring only a temporary reset of the computer.

1.3.3 Results

The SAI Loran-C navigation system was installed on the tug ERNEST M on March 13, 1979 for a period of slightly more than one month. During that time, a total of 35 disposal operations were conducted in the Central Long Island Sound Disposal Site at three designated disposal points in the vicinty of the mound shown in Figure 1.3.3-1. No problems were experienced with the operation of the computer system or the Loran-C receiver in terms of hardware performance. The initial software package, however produced unacceptable time delays in the smoothing functions which caused difficulties in navigation near the disposal point. Once these functions were corrected, disposal operations were conducted smoothly for the duration of the project.

Initial problems were also encountered as a result of



-72° 53.00'
-72° 52.80'
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-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in
Stamford-
New Haven
South
7 August 1979
TARGET POSITIONS
X - POSIT #1
X - POSIT #2
X - POSIT #3
22.0
22.5
18.5

Figure 1.3.3-1

attempts to use the system beyond the limits of resolution provided by the Loran-C network. Table 1.3.3-1 presents the results of an analysis of error routine, generated as part of the SAI software package, which provides an estimate of the resolution of the Loran-C lattice at a specified point. For the Central Long Island Sound Site the minimum error (i.e. best resolution) found on the X and Y slaves of the 9960 GRI chain is approximately 20 meters. At the beginning of the project, the disposal inspectors were requiring a position within 5 meters of the designated point prior to disposal. Since the precision of the Loran cannot resolve such small offsets, this caused extensive delays in the disposal operation. When readings of $\pm$ 5 meters were obtained, they were merely coincidental and not representative of actual position. Once the criteria for disposal were relaxed to $\pm$ 20 meters, the operation took proceeded smoothly with no delays.

Figure 1.3.3-1 is a contour chart of the disposal site with the designated disposal points indicated by the large crosses and individual dumping operations indicated by the smaller "x". When considering the distribution of these points relative to the designated location, almost all dumping was accomplished within 50 meters of the desired location. A summary of the disposal locations relative to the designed points is presented in Table 1.3.3-2. Although this precision might not be considered accurate enough for placement of contaminated material (depending on the volume), it is certainly adequate for capping, and provides a mechanism for controlling the distribution of material without requiring the movement of a disposal buoy.

A bathymetric survey made on April 2, 1980, (Figure

LATITUDE = 41 08.756N
LONGITUDE = 72 52.581W

LORAN C TIMES FOR GRI 9960:
NANTUCKET, MA: 26544.499
CAROLINA BEACH, NC: 43996.3911

XFORM MATRIX (MICROSEC/MI):

-11.5894905	2.62828306
-2.20944202	8.33967183

INVERSE XFORM MATRIX (METERS/MICROSEC):

-170.014705	53.5808575
-45.0422558	236.266347

LOP VECTORS:
155 METERS/MICROSEC @ 282 DEG. TRUE
214 METERS/MICROSEC @ 345 DEG. TRUE

LOP CROSSING ANGLE: 62 DEG.

GDOP POSITIONAL ERROR ELLIPSE
(METERS/0.1 MICROSEC):
SEMI-MAJOR AXIS: 26.2590347
SEMI-MINOR AXIS: 14.378042
BEARING: 118.656085
RESULTANT ERROR
(METERS/0.1 MICROSEC) = 29.9376852

10 MICROSEC. JUMP:
T1: 1758.80086 METERS
T2: 2422.65753 METERS

LORAN-C RESOLUTION CENTRAL LONG ISLAND SOUND DISPOSAL SITE

TABLE 1.3.3-1

LORAN-C COORDINATES FOR DISPOSAL POINTS
MARCH - APRIL 1980
CENTRAL LONG ISLAND SOUND DISPOSAL SITE

DISPOSAL POINT #1

26543.5 53994.5

Dump	Slave X	Slave Y
DUMP #1	26542.9	43994.7
	26543.1	43994.5
DUMP #2	26543.4	43994.5
DUMP #3	26543.3	43994.6
DUMP #4	26543.2	43994.5
DUMP #5	26543.2	43994.7
	26544.0	43994.8
DUMP #6	26543.3	43994.6
	26543.2	43994.5
DUMP #7	26543.4	43994.5
	26544.2	43994.7
DUMP #8	26543.4	43994.7
	26543.4	43994.7
DUMP #9	26543.5	43994.6
	26543.3	43994.6
DUMP #10	26543.6	43994.6
	26543.7	43994.5
DUMP #11	26543.7	43994.6
	26543.9	43994.7

DISPOSAL POINT #2

26542.3 43993.9

Dump	Slave X	Slave Y
DUMP #12	26542.1	43993.8
	26541.8	43993.4
DUMP #13	26542.2	43994.0
	26542.2	43993.6
DUMP #14	26542.2	43993.9
	26542.1	43994.0
DUMP #15	26542.5	43993.9
	26542.5	43993.9
DUMP #16	26542.1	43993.5
DUMP #17	26542.2	43994.0
	26542.1	43993.9
DUMP #18	26542.4	43993.9
	26542.4	43994.0
DUMP #19	26542.5	43994.0
	26542.6	43994.0
DUMP #20	26542.4	43993.8
	26542.4	43993.7
DUMP #21	26542.3	43993.6
	26542.5	43994.2
DUMP #22	26542.3	43993.9

DISPOSAL POINT #3

26541.8 43993.7

Dump	Slave X	Slave Y
DUMP #23	26541.8	43993.5
	26541.8	43993.5
DUMP #24	26541.9	43993.8
	26541.9	43993.8
DUMP #25	26542.0	43993.8
	26542.5	43994.4
DUMP #26	26541.9	43993.6
	26542.1	43993.6
DUMP #27	26541.7	43993.2
	26542.4	43993.3
DUMP #28	26541.8	43993.7
	26541.7	43993.6
DUMP #29	26541.8	43993.7
	26541.9	43993.7
DUMP #30	26541.8	43993.8
	26541.7	43993.6
DUMP #31	26542.0	43993.8
	26542.0	43993.7
DUMP #32	26541.9	43993.9
	26541.8	43993.8
DUMP #33	26541.8	43993.4
	26541.9	43993.1
DUMP #34	26541.9	43993.8
	26542.9	43993.8

TABLE 1.3.3-2

1.3.3-2) clearly indicates the development of a small mound approximately 300 m west of the main disposal point which was created to cover the Stamford material exposed at that location. This mound is emphasized by the box drawn on the chart enclosing the area of coverage. An unexpected benefit of the Loran system resulted from the procedure of equalizing the course made good with the bearing to the disposal point. Prior to installation of the system, tug operators were required to dead reckon to the disposal area. Navigation was extremely difficult because the compass was nearly useless due to offset of the tug's course required to maintain the scow in a straight line, magnetic deviations caused by the mass of material in the scow alongside, and the corrections required to compensate for current set and wind drift. Consequently, significant time was frequently required to find the disposal buoy, particularly at night or in bad weather. With the SAI computer controlled Loran system the tug was able to steer directly to the disposal point as shown by the course tracks presented in Figure 1.3.3-3. This ability to steer a straight course to the site greatly reduced the time and fuel necessary for the dumping operation during low visibility.

1.3.5 Summary

The use of computer enhanced Loran-C navigation to control disposal operations at the Central Long Island Sound Disposal site was extremely successful. The ability to distribute material as desired without costly buoy relocation makes this procedure an effective approach to "capping" operations, or any disposal operation where a disposal buoy is impractical. Furthermore, the ability to improve the navigation of the tug and

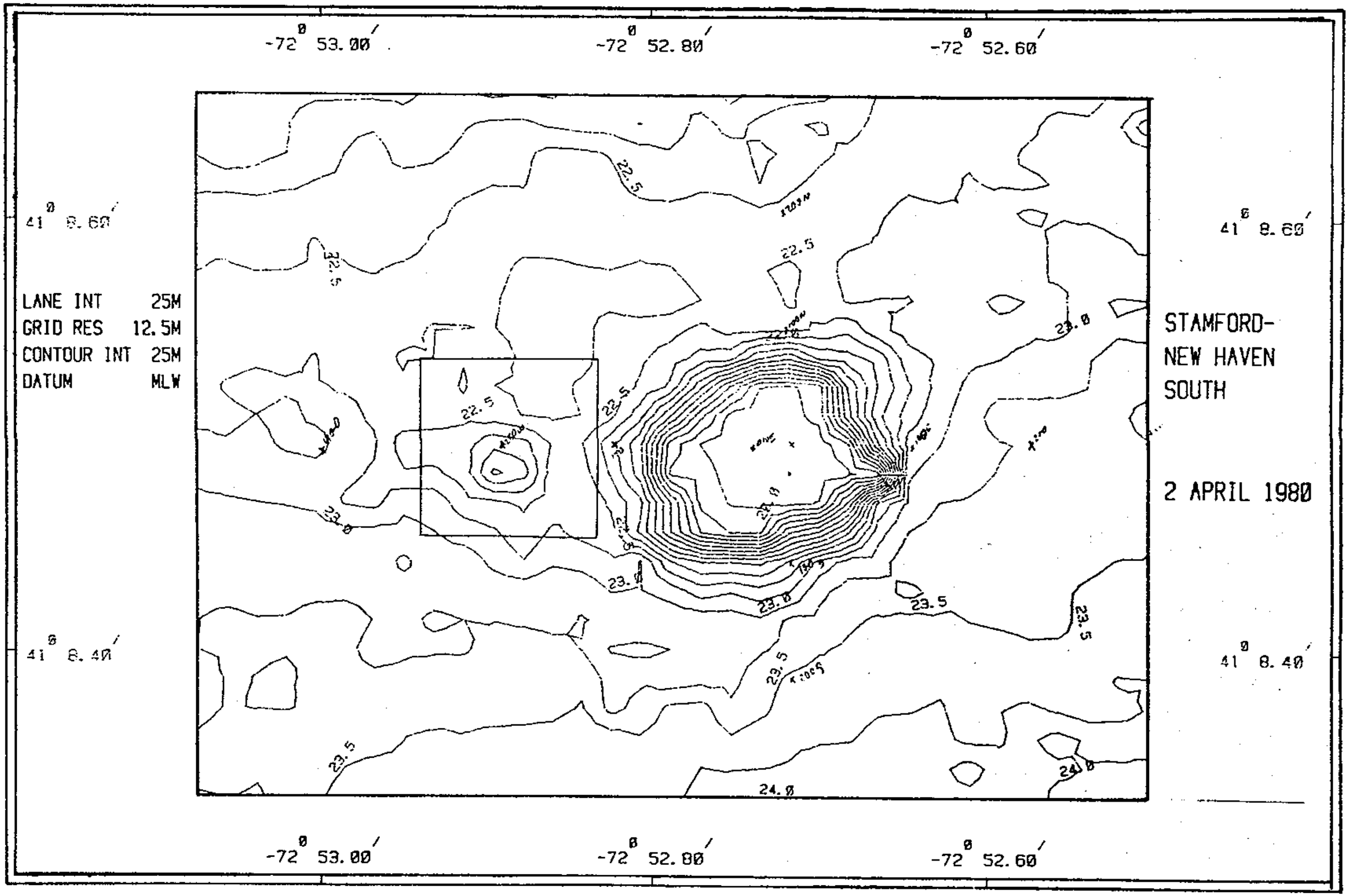
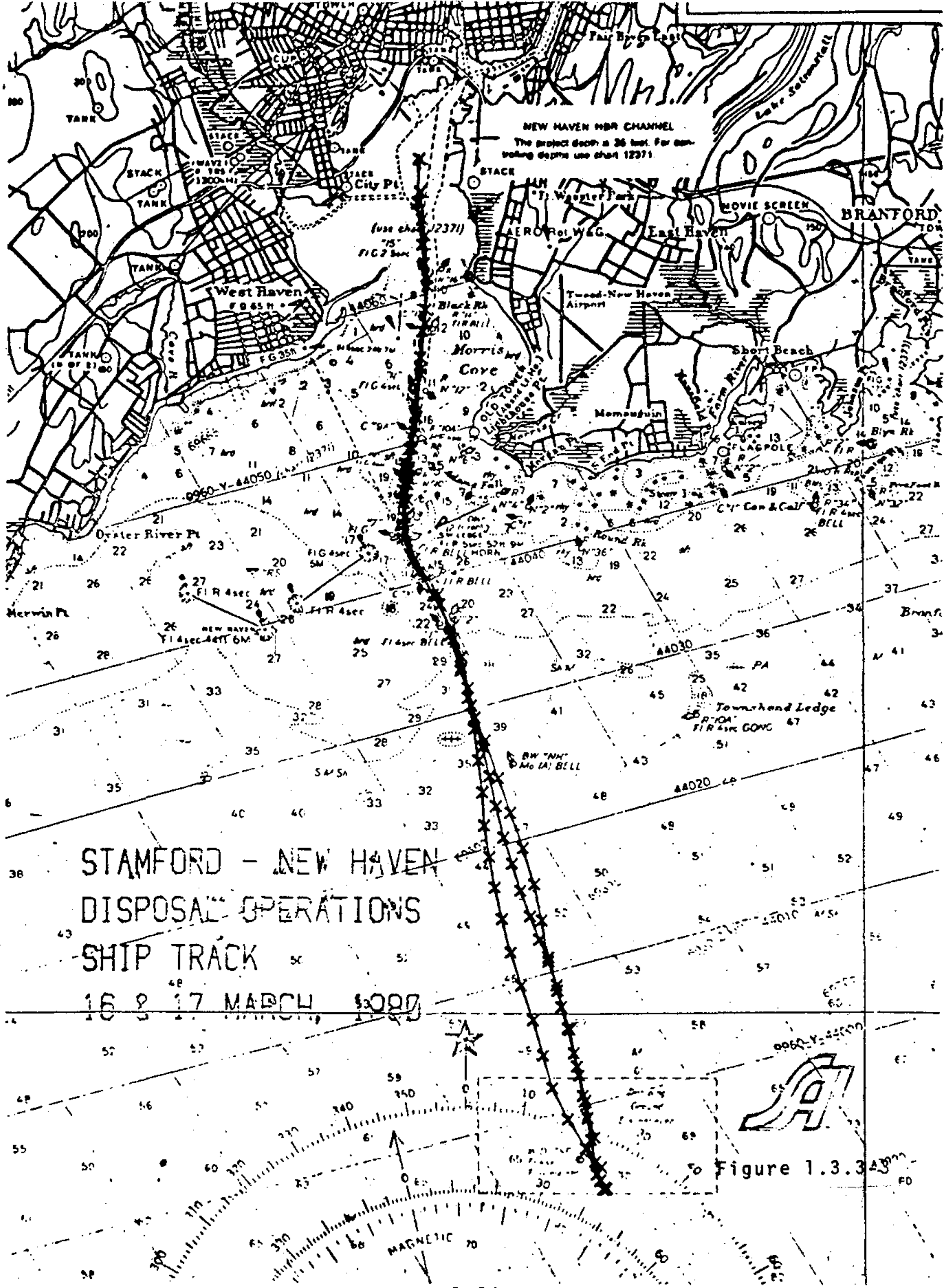

-72° 53.00'
-72° 52.80'
-72° 52.60'
41° 8.60'
41° 8.40'
LANE INT 25M
GRID RES 12.5M
CONTOUR INT 25M
DATUM MLW
STAMFORD-
NEW HAVEN
SOUTH
2 APRIL 1980
22.5
23.0
23.5
24.0

Figure 1.3.3-2



NEW HAVEN HBR CHANNEL
The project depth is 35 feet. For controlling depths use chart 12371.
City Pt
West Haven
East Haven
BRANFORD
Tweed-New Haven Airport
Black Rk
Morris Cove
Momauguin
Short Beach
Oyster River Pt
Round Rk
Townshend Ledge
STAMFORD - NEW HAVEN
DISPOSAL OPERATIONS
SHIP TRACK
16 & 17 MARCH 1980
MAGNETIC

Figure 1.3.3

scow can save time and fuel during periods of low visibility. Using this procedure, the New England Division has been able to employ effective managment control to cap isolated exposures of relatively contaminated material, and to increase the cap thickness on the southern margin of the disposal mound. The successful use of these procedures during the Central Long Island Sound disposal operations indicates that the navigational and management package developed by SAI will be applicable at other disposal sites.

2.0 MEASUREMENTS OF DREDGE MATERIAL STABILITY

2.0 MEASUREMENTS OF DREDGE MATERIAL STABILITY

2.1 Introduction

Previous DAMOS reports have discussed the procedures used to measure the accumulation and stability of disposed dredged material through precision replicate bathymetric surveys. This same approach has been continued during 1980, and improved somewhat through more closely spaced survey lines over generally smaller survey grids. Elaboration of the extensive survey procedures which were used at the Central Long Island Sound Disposal Site are presented in Section 3.0. This section will provide more general data on the other sites studied, and summarize the results of disposal operations during the past year.

2.2 Instrumentation and Procedures

During 1980, an important change was made in the hardware used to conduct surveys when the operational aspects of the DAMOS program changed from NUSC to SAI. Rather than continuing with the Hewlett Packard 9825A computer system with the associated hardware constraints and expenses, a new system was developed using an Apple II microcomputer, interfaced with a new Model 540 Del Norte Trisponder and a new Edo Western multi frequency fathometer system. All of this instrumentation utilizes state of the art microprocessing equipment which greatly facilitates interfacing reduces costs, and generally increases the speed of the computing operations.

Visual displays to the helmsman for control of the ship are now much more comprehensive and are projected over a video monitor to provide a complete relative picture of the ship's orientation and position relative to a desired point location or survey course. All data are now recorded on "floppy disk" media so that more rapid data acquisition and analysis can be readily accomplished. In addition, several types of positioning systems, such as Loran-C, can now be interfaced to the system to provide more flexibility in the survey, sampling, or disposal management modes of operation.

In terms of survey procedures, the only important changes are associated with increasing the resolution through decreased lane spacing. All surveys with the exception of the New London site are now run with 25 meter lane intervals. Since the grid spacing is one half of the lane interval, this increases the resolution by a factor of four when the spacing changes from 50 to 25 meters. With this increased resolution and the more rapid data acquisition possible with the new computer system, the measurement of dredge material volume changes, and sediment distribution is even more accurate than previously obtained.

2.3 Portland, Maine Disposal Site

As discussed in previous reports, a major effort was expended on selection of a suitable disposal area for material dredged from Portland Harbor. The result of that effort was a site located in a sandy valley at a depth of slightly greater than 60 m, surrounded by rocky ledges reaching minimum depths of between 40 and 50 m (Figure 2.3-1). During August 1979, a taut wire moored disposal buoy was placed at 43° 34.11' N and 70° 01.91'W and disposal operations began in September 1979.

A bathymetric survey conducted during April 1980, showed no important changes in the topography of the site (Figure 2.3-2).

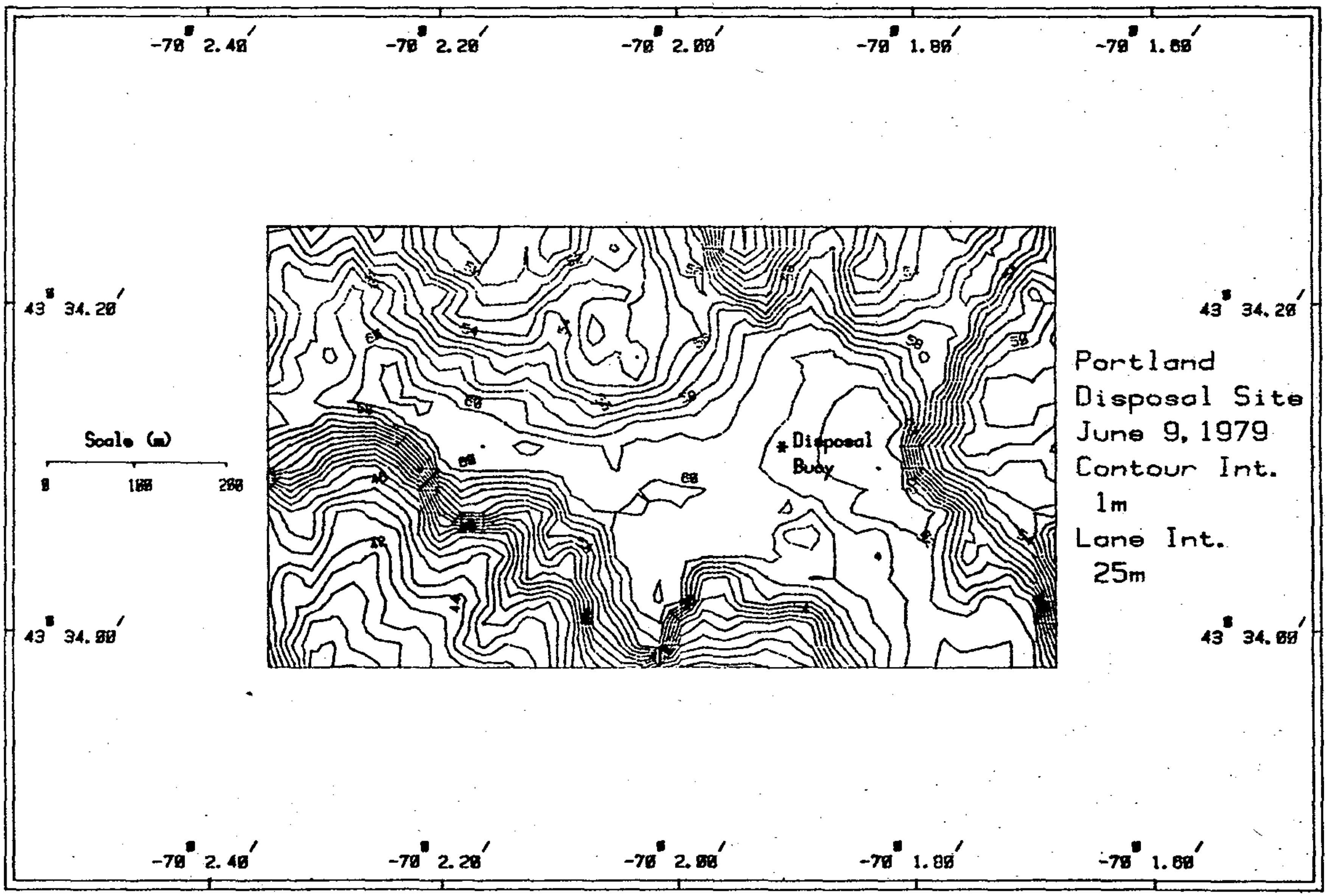
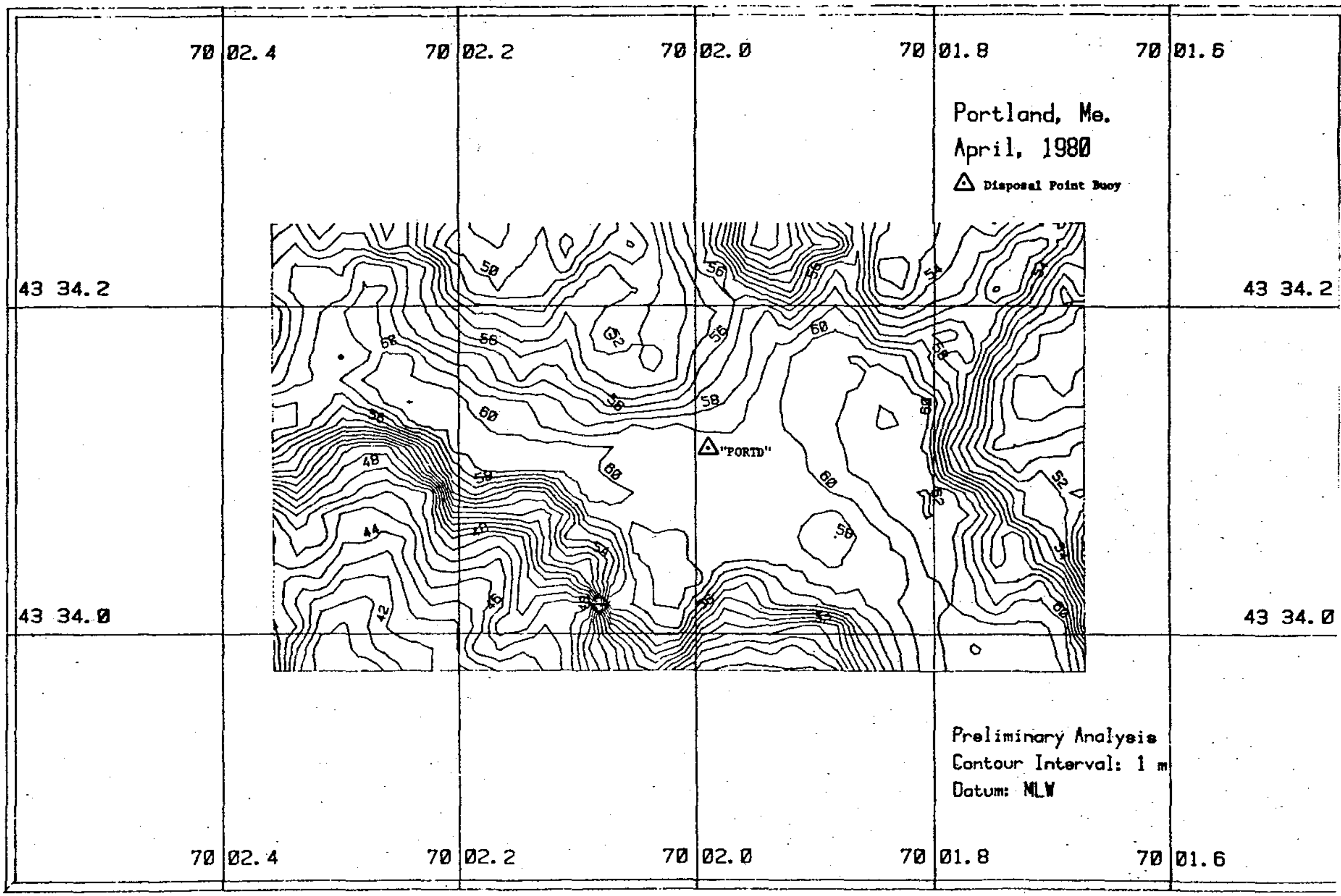

-70° 2.40'
-70° 2.20'
-70° 2.00'
-70° 1.80'
-70° 1.60'
43° 34.20'
43° 34.00'
Scale (m)
0
100
200
Disposal Buoy
Portland
Disposal Site
June 9, 1979
Contour Int.
1m
Lane Int.
25m

Figure 2.3-1



70 02.4
70 02.2
70 02.0
70 01.8
70 01.6
Portland, Me.
April, 1980
Disposal Point Buoy
43 34.2
43 34.0
"PORTD"
Preliminary Analysis
Contour Interval: 1 m
Datum: MLW

Figure 2.3-2

However, sediment samples at the disposal point did indicate the presence of dredged material. A second survey, performed in August 1980, revealed the presence of a definite mound south of the disposal buoy reaching a thickness of four meters in some areas (Figure 2.3-3). This thickness had increased to over six meters by December 1980 (Figure 2.3-4) and the mound was spread over a diameter of more than 200 meters.

Although the mound described above developed in the vicinity of the disposal buoy, other evidence indicates that the dredge material was spread over a somewhat larger area. Sediment samples taken radially from the center of the disposal point indicate that dredged material extends to the margins of the valley in both the east and south directions and to a significant distance in the west direction. The only natural sediment now exposed in the valley is found on the northern margin of the site.

This spread of material is probably the result of three interrelated aspects of the Portland disposal operation. First, some of the sediments dredged from this harbor were less cohesive than those found in Connecticut harbors, probably because of continued stirring by large oil tankers maneuvering in the shallow harbor. Second, these less cohesive muds were dropped through nearly three times the depth of water encountered during disposal operations in Long Island Sound which would tend to increase dispersion through higher terminal velocities and greater entrainment of water. Finally, the location of the site in open ocean waters required disposal under adverse wind and wave conditions which prohibited the extremely accurate $\pm$ 10 m disposal operations used in the sound. At this site, the radius of

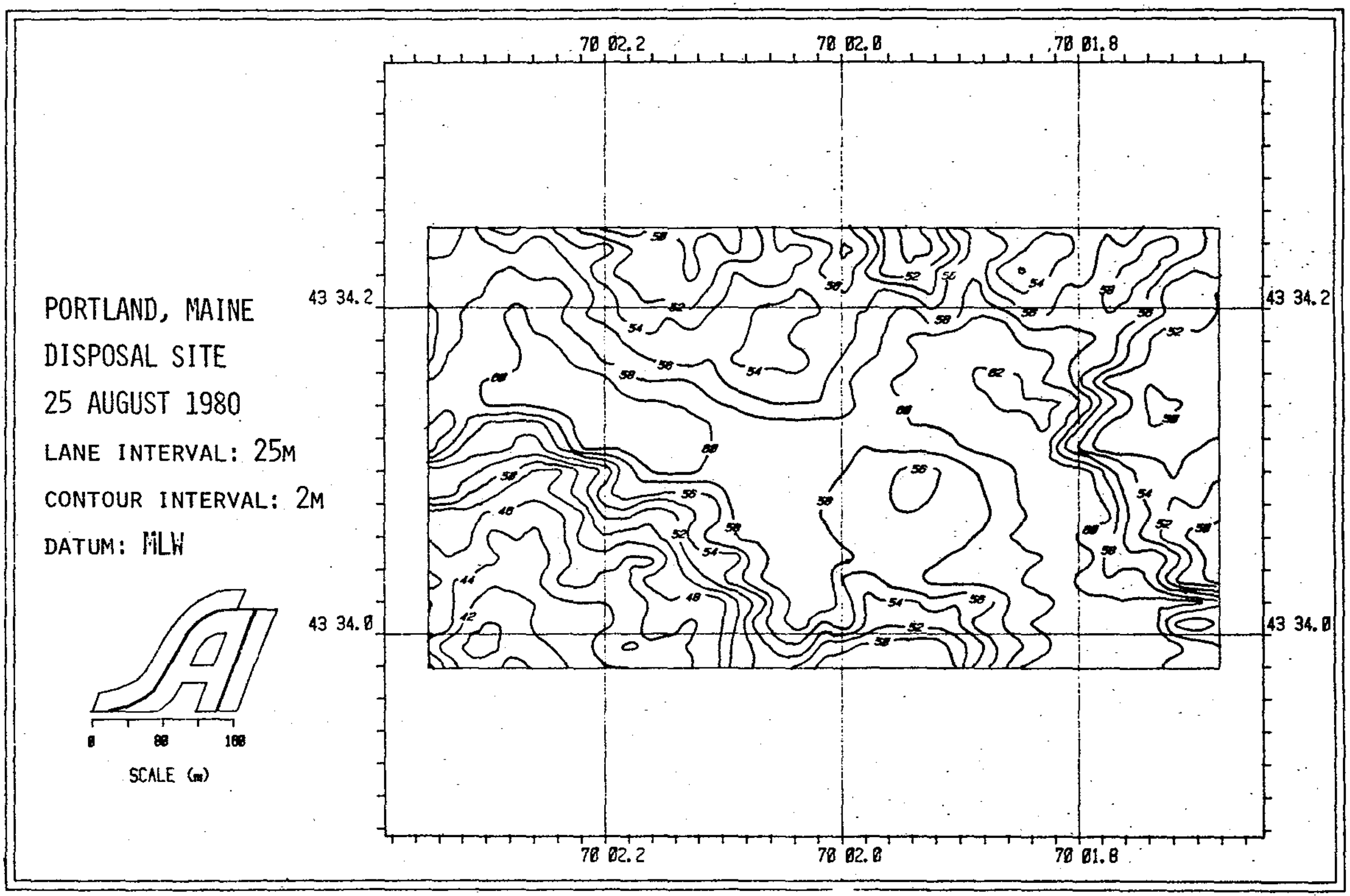
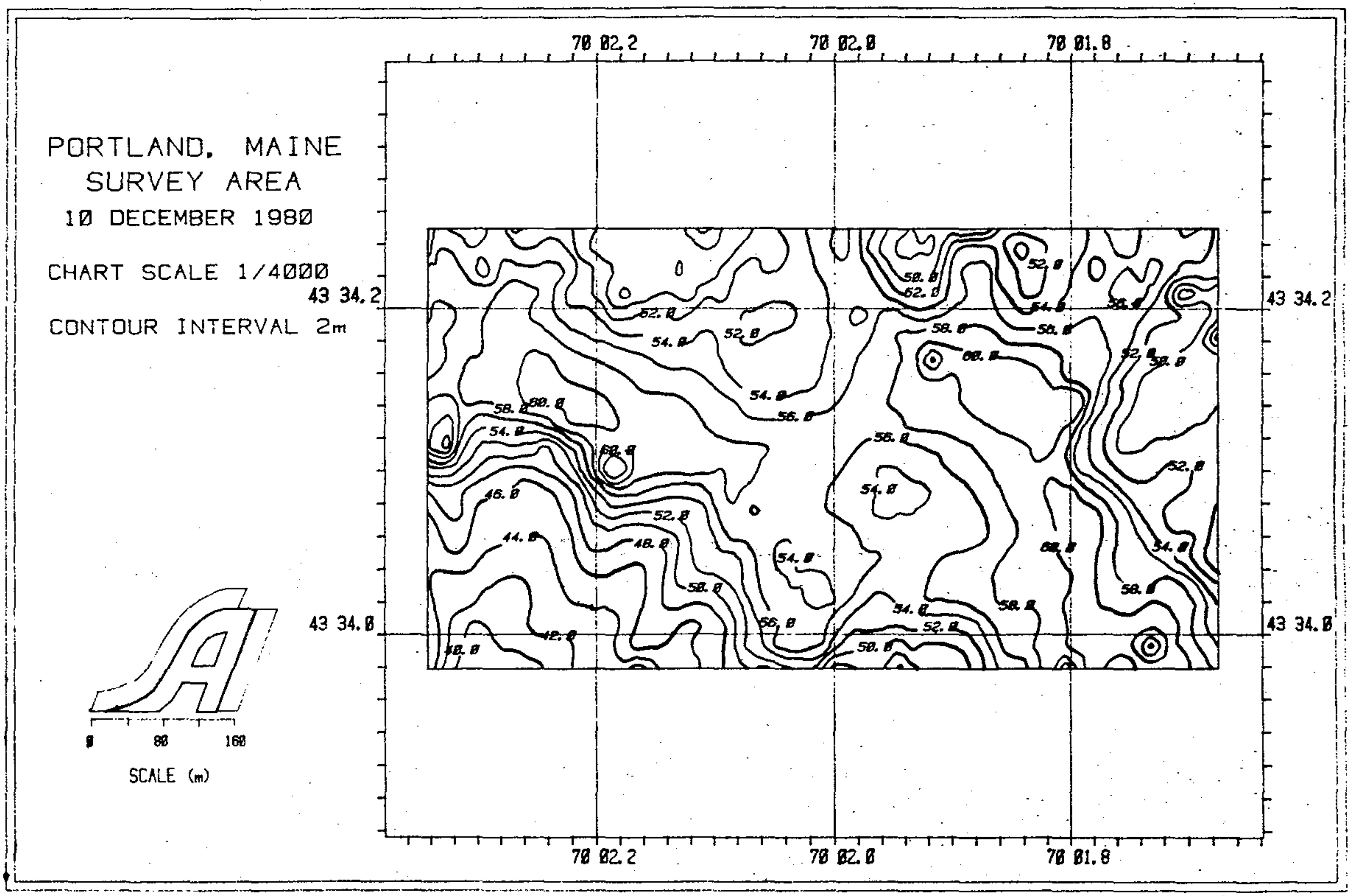

PORTLAND, MAINE
DISPOSAL SITE
25 AUGUST 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: 2M
DATUM: MLW
0
50
100
SCALE (m)
70 02.2
70 02.0
70 01.8
43 34.2
43 34.0

Figure 2.3-3



PORTLAND, MAINE
SURVEY AREA
10 DECEMBER 1980
CHART SCALE 1/4000
CONTOUR INTERVAL 2m
70 02.2
70 02.0
70 01.8
43 34.2
43 34.0
0
80
160
SCALE (m)

Figure 2.3-4

disposal must have been on the order of $\pm$ 50 to 75 m relative to the disposal buoy..

The results of the monitoring effort at Portland indicate that the selection of the disposal site in a deep valley was probably an excellent choice since the steep slopes on the margins contribute to containment of the material. Furthermore, although a mound of dredged material was formed, this study indicates that disposal in deep, open ocean sites will not be as precise and concentrated as in shallower more protected areas. Consequently, if covering or capping operations are proposed, a relatively larger volume of clean material will be required to be certain of complete coverage.

Although the coverage of a larger area (relative to the Long Island Sound Disposal Site) was observed in the Portland area, it is important to note that the volume of material disposed at the Portland site was nearly twice that dumped at any one of the Central Long Island Sound disposal points and, therefore, more spreading would be expected based on this factor alone. Future application of point dumping procedures at the Boston Foul Ground should provide additional information on deep water disposal since that site will have much less topographic relief than the Portland site.

2.4 New London Disposal Site

Disposal operations continued at the New London disposal site as Phase III and Phase IV dredging occurred in the Thames River. Figure 2.4-1 is a survey of the site made in August 1979 after completion of Phase II disposal. The major features shown on this chart are the relict disposal mound in the northern

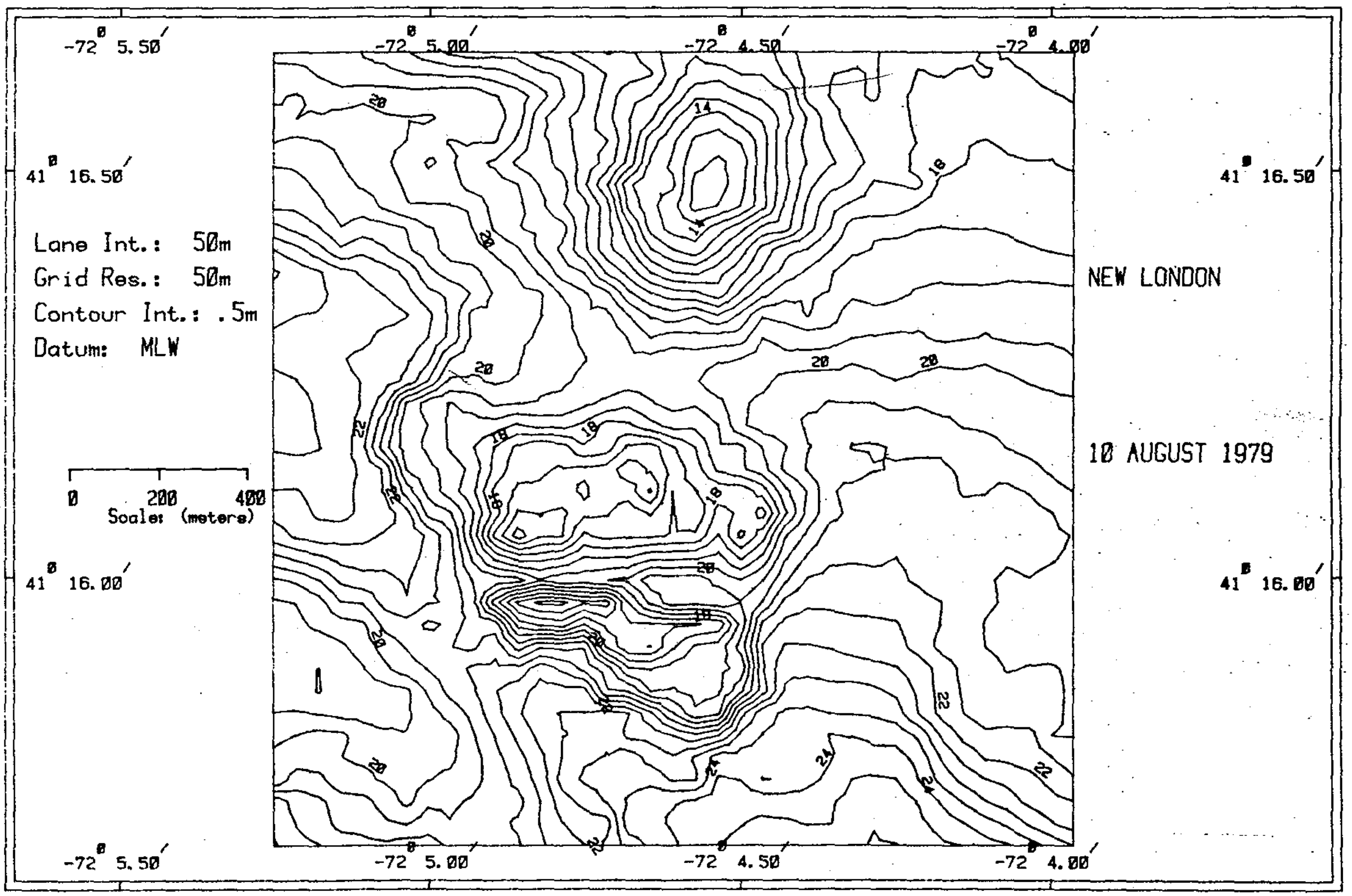
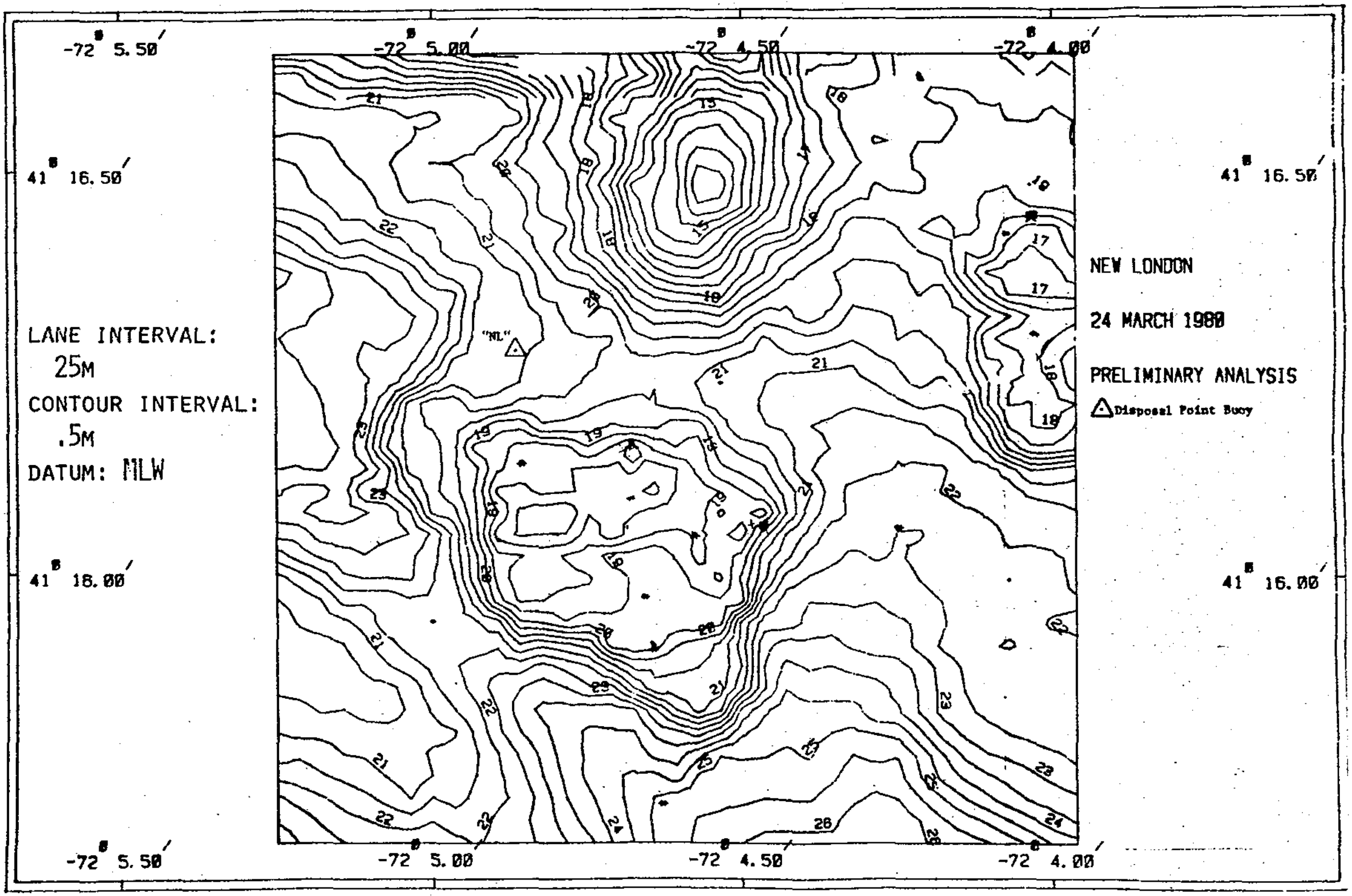

-72° 5.50'
-72° 5.00'
-72° 4.50'
-72° 4.00'
41° 16.50'
41° 16.00'
Lane Int.: 50m
Grid Res.: 50m
Contour Int.: .5m
Datum: MLW
0 200 400
Scale: (meters)
NEW LONDON
10 AUGUST 1979
14
18
20
22
24

Figure 2.4-1

portion of the site, and the actively used southern mound. Some errors in recording caused irregular depths to occur on the top of the mound and these should not be considered valid.

Phase III disposal operations took place in the northeast corner of the disposal area under control of a taut wire moored marker buoy. The objective of this operation was to create a third mound slightly east of the present deposits in order to create a depression for future disposal of more contaminated material. The survey conducted on 24 March 1980 (Figure 2.4-2) indicated that a third mound had indeed been created, however, it was located farther east than expected. Investigations into the reasons for this showed that the disposal buoy which was placed with Loran-C navigation control was not exactly at the specified latitude and longitude even though it was placed at the correct Loran-C coordinates. Obviously, the accuracy of Loran-C in an uncalibrated mode was not sufficient for such management procedures. Subsequent disposal marker deployment have all been accomplished using microwave navigation systems or previously calibrated Loran-C coordinates.

Following the March survey, the disposal marker was moved west to provide a disposal point for additional material being dredged as part of Phase III. This point was selected to provide a deposit between the three mounds. Results of a survey made on 10 June 1980, following completion of the dredging operation (Figure 2.4-3), indicated a distinct circular mound was created with a minimum depth of 14.5 m. This survey had several lanes with bad data located in the southern portion of the survey which were edited by the analysis software.



-72° 5.50'
-72° 5.00'
-72° 4.50'
-72° 4.00'
41° 16.50'
41° 16.00'
LANE INTERVAL:
25M
CONTOUR INTERVAL:
.5M
DATUM: MLW
"NL"
NEW LONDON
24 MARCH 1980
PRELIMINARY ANALYSIS
Disposal Point Buoy

Figure 2.4-2

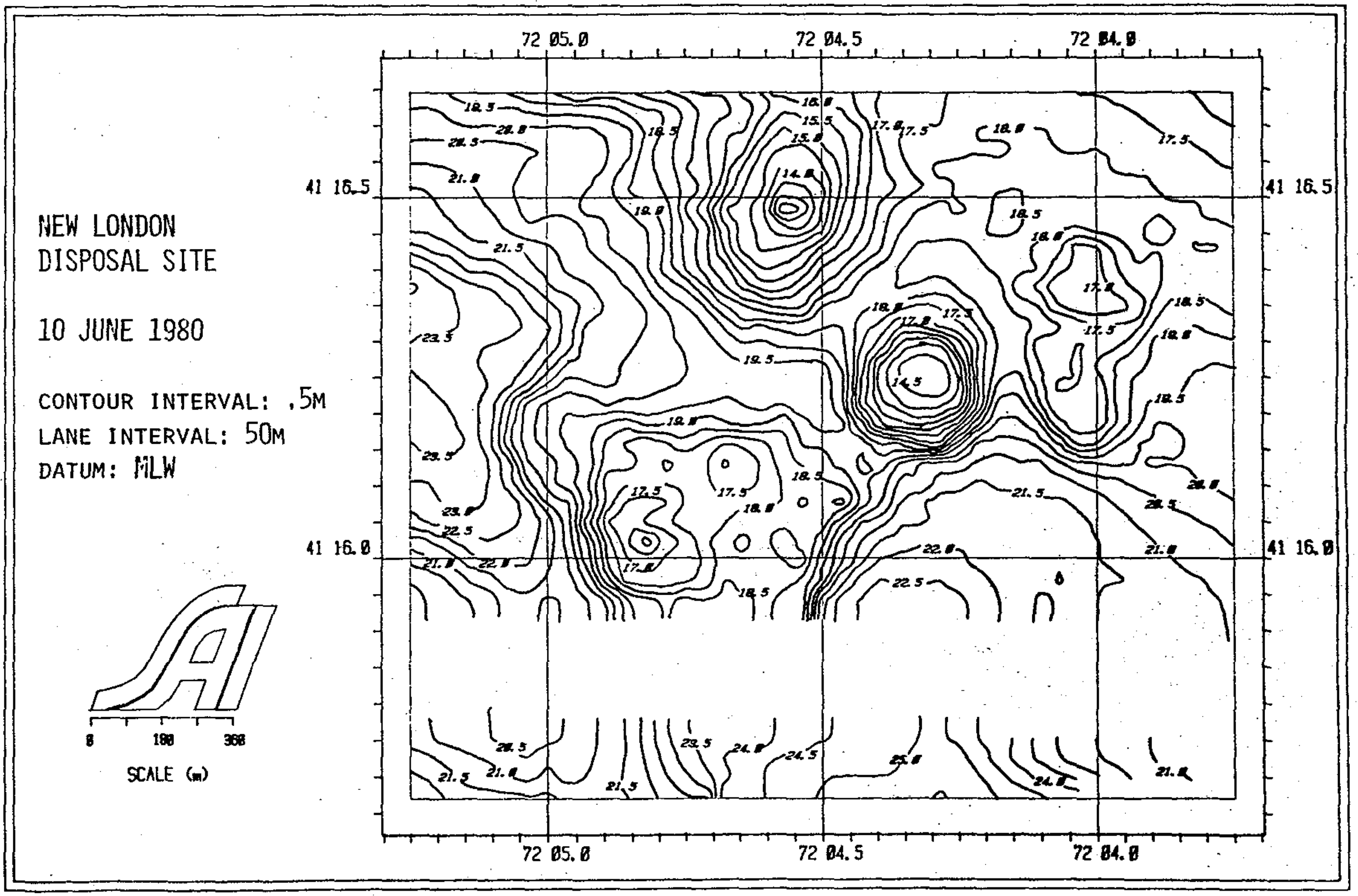

NEW LONDON
DISPOSAL SITE
10 JUNE 1980
CONTOUR INTERVAL: .5M
LANE INTERVAL: 50M
DATUM: MLW
0 100 300
SCALE (m)
72 05.0
72 04.5
72 04.0
41 16.5
41 16.0

Figure 2.4-3

A monitoring survey conducted in August 1980 (Figure 2.4-4) showed very little change in any areas of the disposal site indicating that disposal of the Phase III material had been accomplished in such a manner as to provide a stable deposit.

During the Fall of 1980, Phase IV disposal took place at a point midway between, and slightly west, of the north and south disposal mounds. Preliminary results of a survey conducted on 20 January 1981 (Figure 2.4-5) showed that material had built up in the area of the disposal point to a minimum depth of 17 meters and that the distinct mound created by Phase II disposal had been reduced to a similar depth. In general, the entire region between mounds had reached an equilibrium somewhere around 17 to 18 meters.

Disposal at the New London site has now continued for several years and relatively large volumes of material have been placed on the site. Although there have been minor adjustments in the topography of the dredged material mounds after disposal, no major loss of sediment has occurred and no impacts related to dispersal of the material by currents and wave action have been observed. In summary, the site remains stable in spite of the relatively high energy and intense utilization of the area by ship traffic, commercial fishermen and recreational boaters.

2.5 Central Long Island Sound Disposal Area

Section 3.0 will provide a detailed summary of the monitoring efforts directed towards the disposal of Stamford and New Haven dredged material through the end of 1979. During 1980,

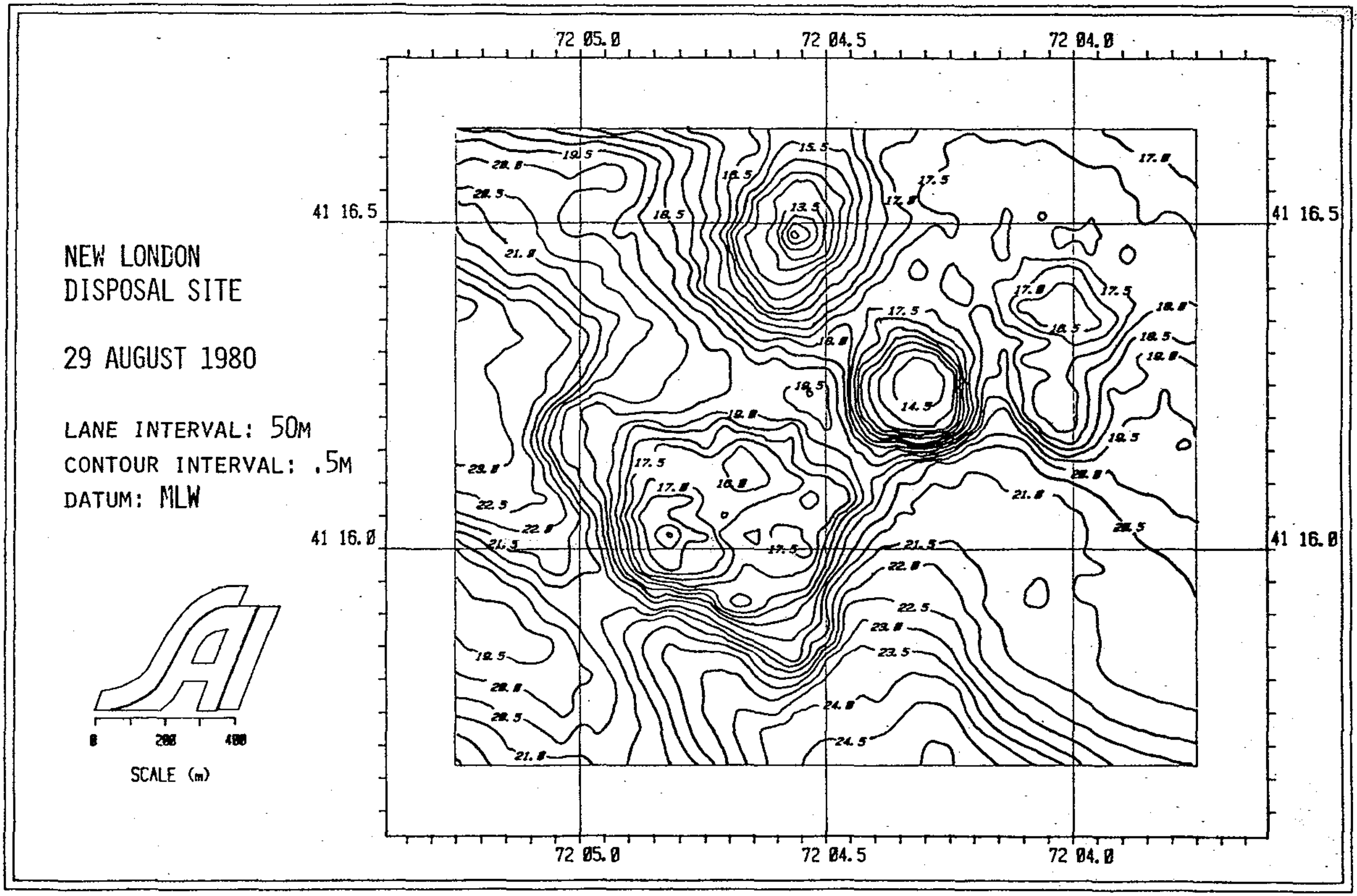

NEW LONDON
DISPOSAL SITE
29 AUGUST 1980
LANE INTERVAL: 50M
CONTOUR INTERVAL: .5M
DATUM: MLW
0 200 400
SCALE (m)
72 05.0
72 04.5
72 04.0
41 16.5
41 16.0

Figure 2.4-4

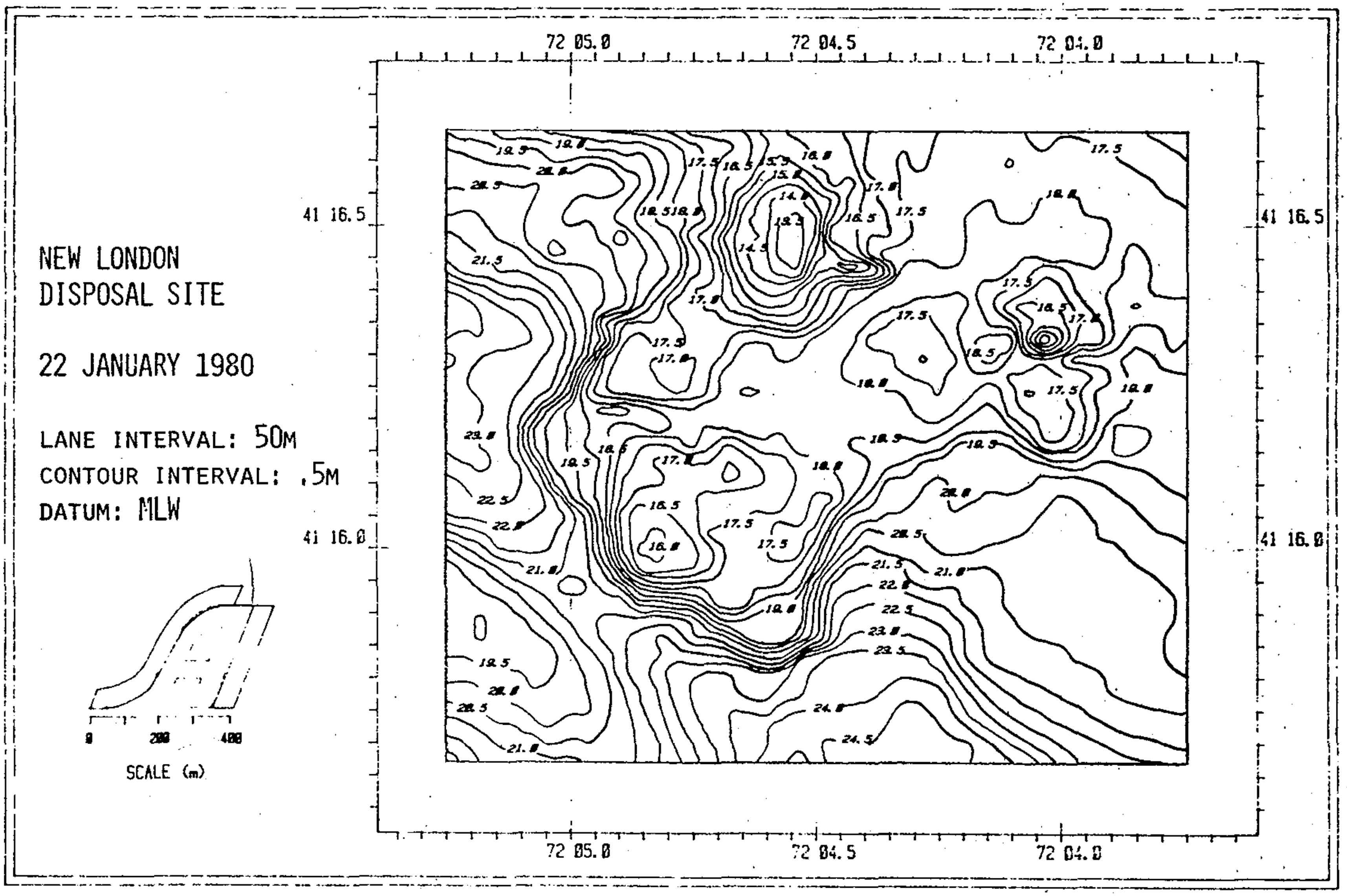

NEW LONDON
DISPOSAL SITE
22 JANUARY 1980
LANE INTERVAL: 50M
CONTOUR INTERVAL: .5M
DATUM: MLW
72 05.0
72 04.5
72 04.0
41 16.5
41 16.0
0
200
400
SCALE (m)

Figure 2.4-5

continued monitoring of these sites took place and additional disposal of material from Norwalk Harbor was accomplished within the Central Long Island Sound Disposal Area.

2.5.1 Stamford-New Haven South Site

As discussed in an earlier section on disposal management, additional material from New Haven was deposited on the South mound during March and April, 1980 and a survey of the site was made on 2 April 1980 to evaluate the results of that operation (Figure 1.3.4-2). The end of the Loran-C controlled disposal in April 1980 marked the completion of the Stamford-New Haven project and no further disposal took place at either the STNH-South or North sites.

Post disposal monitoring continued through 1980 and three surveys were conducted during the study period, one on June 12, 1980 (Figure 2.5.1-1), the second on 8 September 1980 (Figure 2.5.1-2 and a third survey on January 26, 1981 (Figure 2.5.1-3). The results of these surveys indicate that the mound was extremely stable during the entire year. Vertical depth sections through the mound, for each of the surveys, are superimposed in Figure 2.5.1-4. The June and September profiles are virtually identical, and the January profiles show only small changes in topography, particularly on the eastern margins of the mound.

In summary, the silt from New Haven appears to be maintaining itself as an effective cap of Stamford sediment. Continued monitoring is planned to determine whether this situation persists and to indicate whether the "capping" procedures used on this project continue to be successful.

2.5.2 Stamford-New Haven North Site

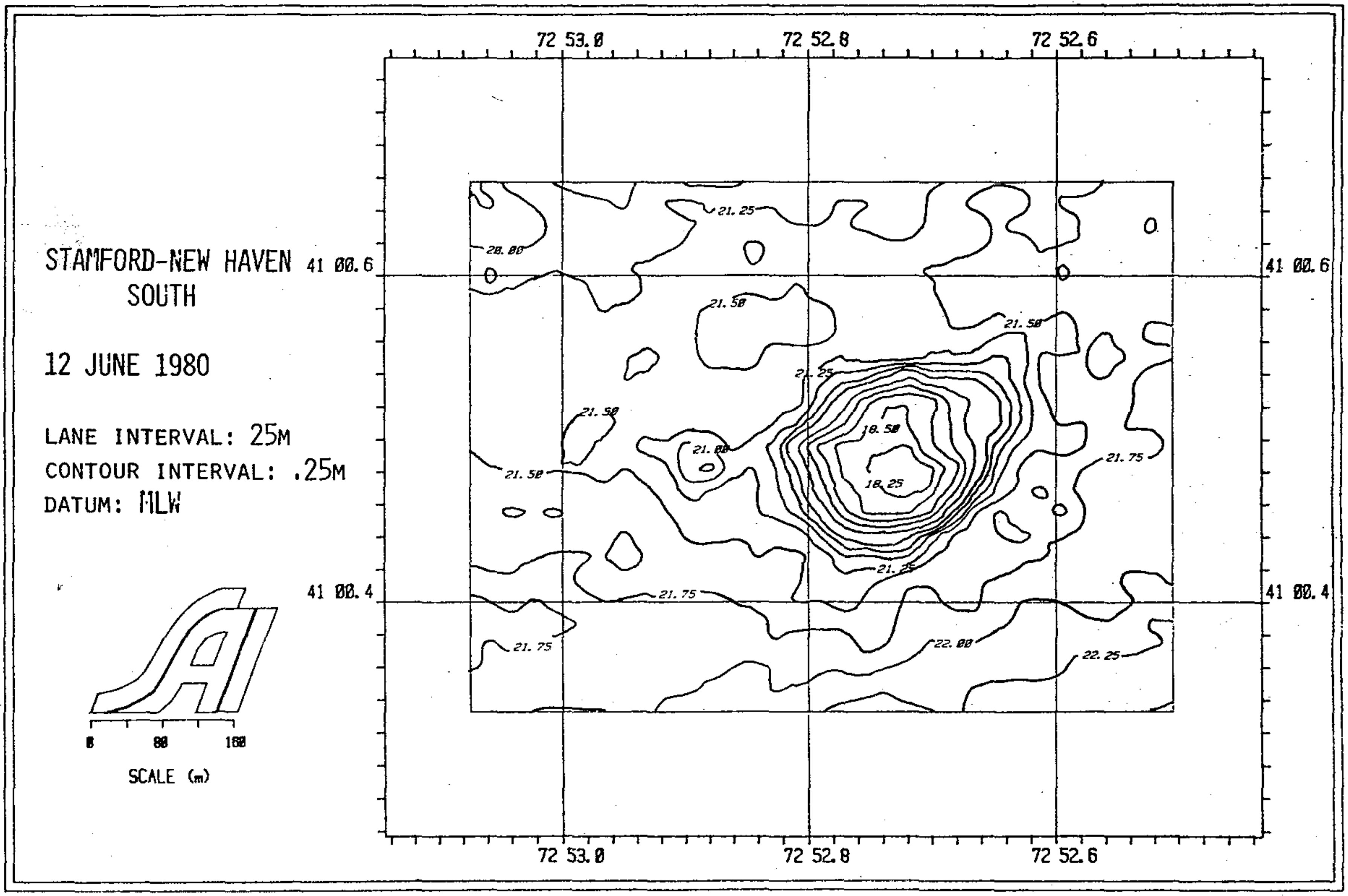
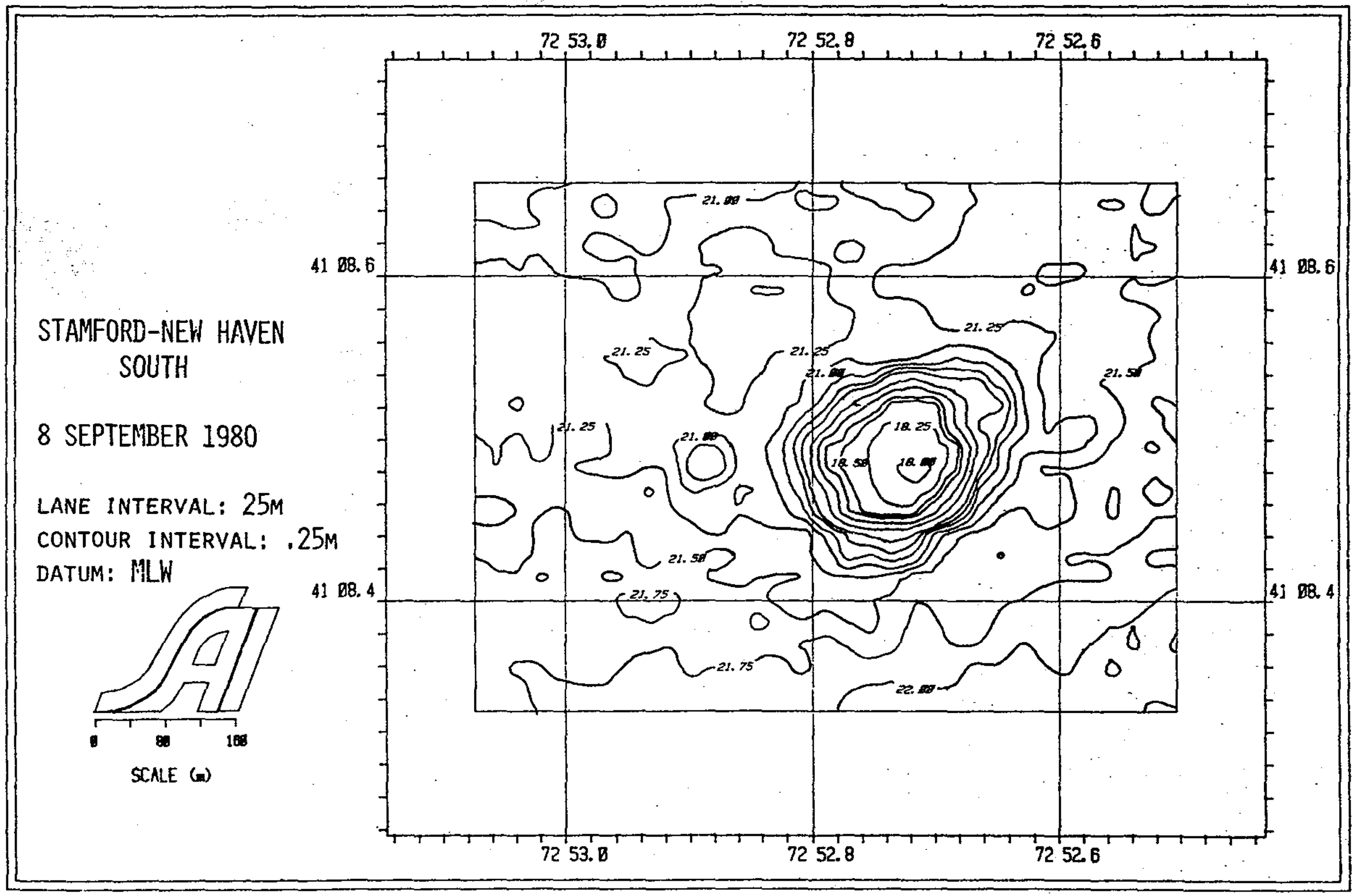

STAMFORD-NEW HAVEN
SOUTH
12 JUNE 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: .25M
DATUM: MLW
0 80 160
SCALE (m)
72 53.0
72 52.8
72 52.6
41 00.6
41 00.4
21.25
20.00
21.50
21.75
21.00
18.50
18.25
22.00
22.25

Figure 2.5.1-1



STAMFORD-NEW HAVEN
SOUTH
8 SEPTEMBER 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: .25M
DATUM: MLW
0
80
160
SCALE (m)
72 53.0
72 52.8
72 52.6
41 08.6
41 08.4
21.00
21.25
21.50
21.75
22.00
18.25
18.50
18.00

Figure 2.5.1-2

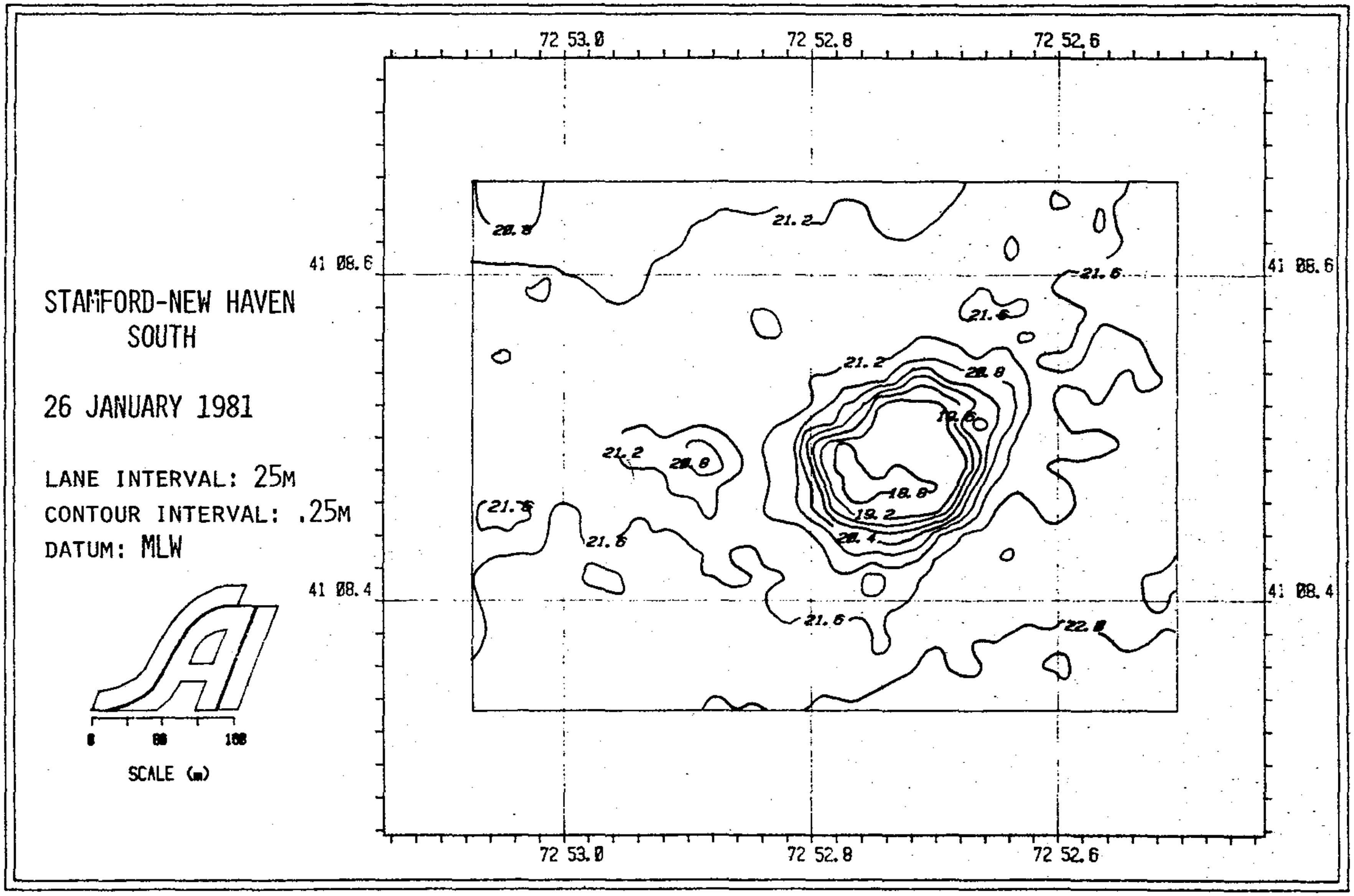

STAMFORD-NEW HAVEN
SOUTH
26 JANUARY 1981
LANE INTERVAL: 25M
CONTOUR INTERVAL: .25M
DATUM: MLW
SCALE (m)
72 53.Ø
72 52.8
72 52.6
41 Ø8.6
41 Ø8.4
21.2
21.6
20.8
20.4
19.2
18.8
22.Ø

Figure 2.5.1-3

STAMFORD-NEW HAVEN SOUTH
VERTICAL DEPTH PROFILES

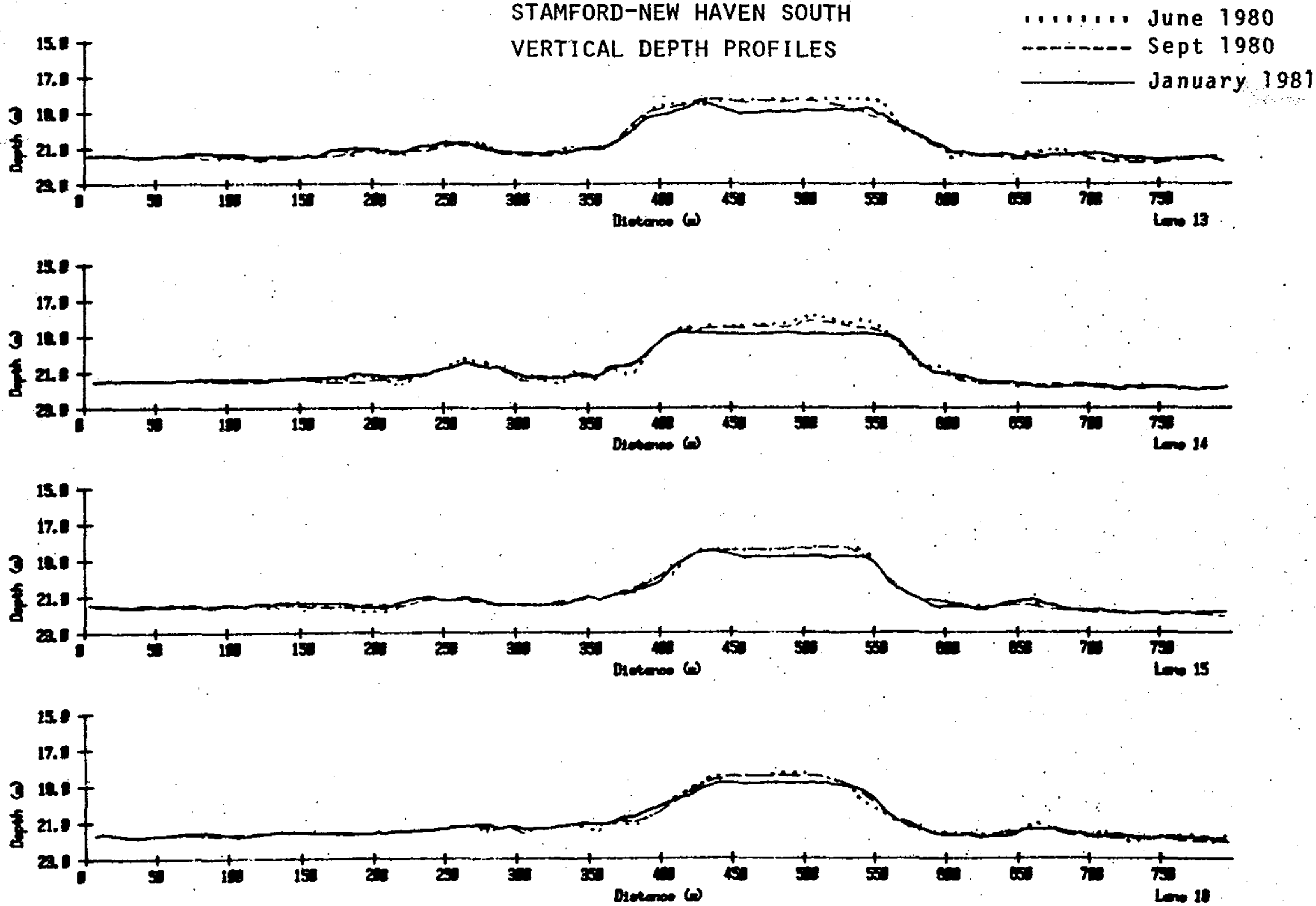


Figure 2.5.1-4

Similar surveys were conducted at the STNH-North disposal site to provide a monitoring program for the sand cap. As in the case of the STNH-South site, four surveys were made during the study period. Representative data from the surveys on April 2, 1980 September 3, 1980 are presented in Figures 2.5.2-1 and 2. All of these surveys indicate virtually no change in the topography of the North site which suggests that the sand cap is providing excellent coverage of the Stamford material.

Although the silt cap at the South site appears adequate for capping, it does display a potential for change due to sediment resuspension during winter storm periods as shown by the loss of material during Hurricane David in 1979 and some slight changes in topography during the Fall of 1980. The sand material, on the other hand, has never shown significant movement, and if complete isolation of material is a necessity, sand may prove to be the most effective capping material in terms of physical stability. However, the lack of substantial deposits of sand in areas requiring dredging probably mean that silt will be the more common capping material in the New England region.

2.5.3 New Haven 1974 Deposit

Evaluation of the effects of Hurricane David in 1979 provided the impetus for continued monitoring of the disposal mound created by the 1974 dredging of New Haven harbor. In order to observe changes over the long term, yearly surveys were initiated covering the immediate vicintiy of the mound with a 25m lane interval resolution. The results of a survey conducted on November 15, 1979 (Figure 2.5.3-1) can be compared with a survey conducted on September 2, 1980 (Figure 2.5.3-2). Obviously, no

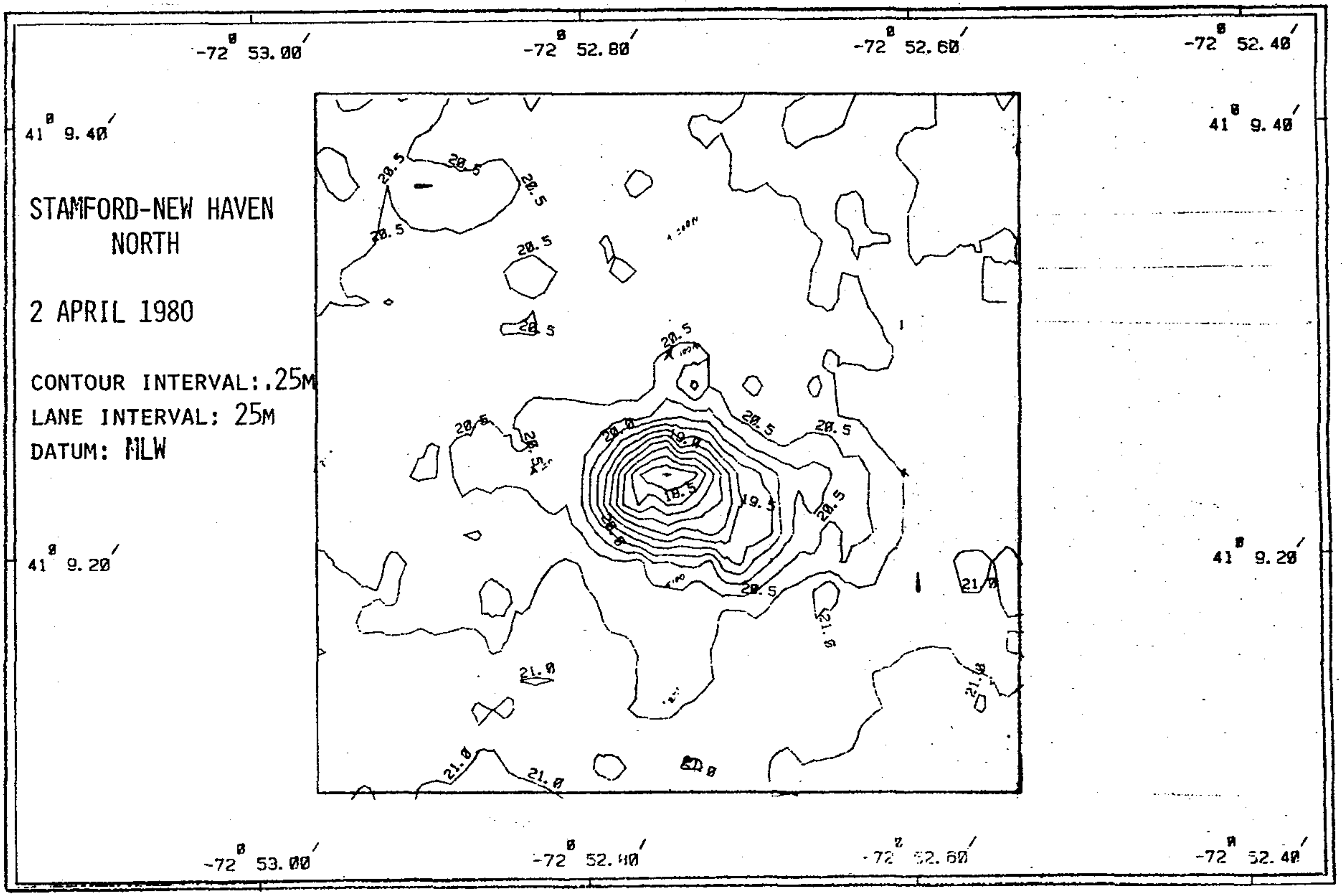

STAMFORD-NEW HAVEN
NORTH
2 APRIL 1980
CONTOUR INTERVAL: .25M
LANE INTERVAL: 25M
DATUM: MLW
-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
20.5
21.0
19.5
19.0
18.5
20.0

Figure 2.5.2-1

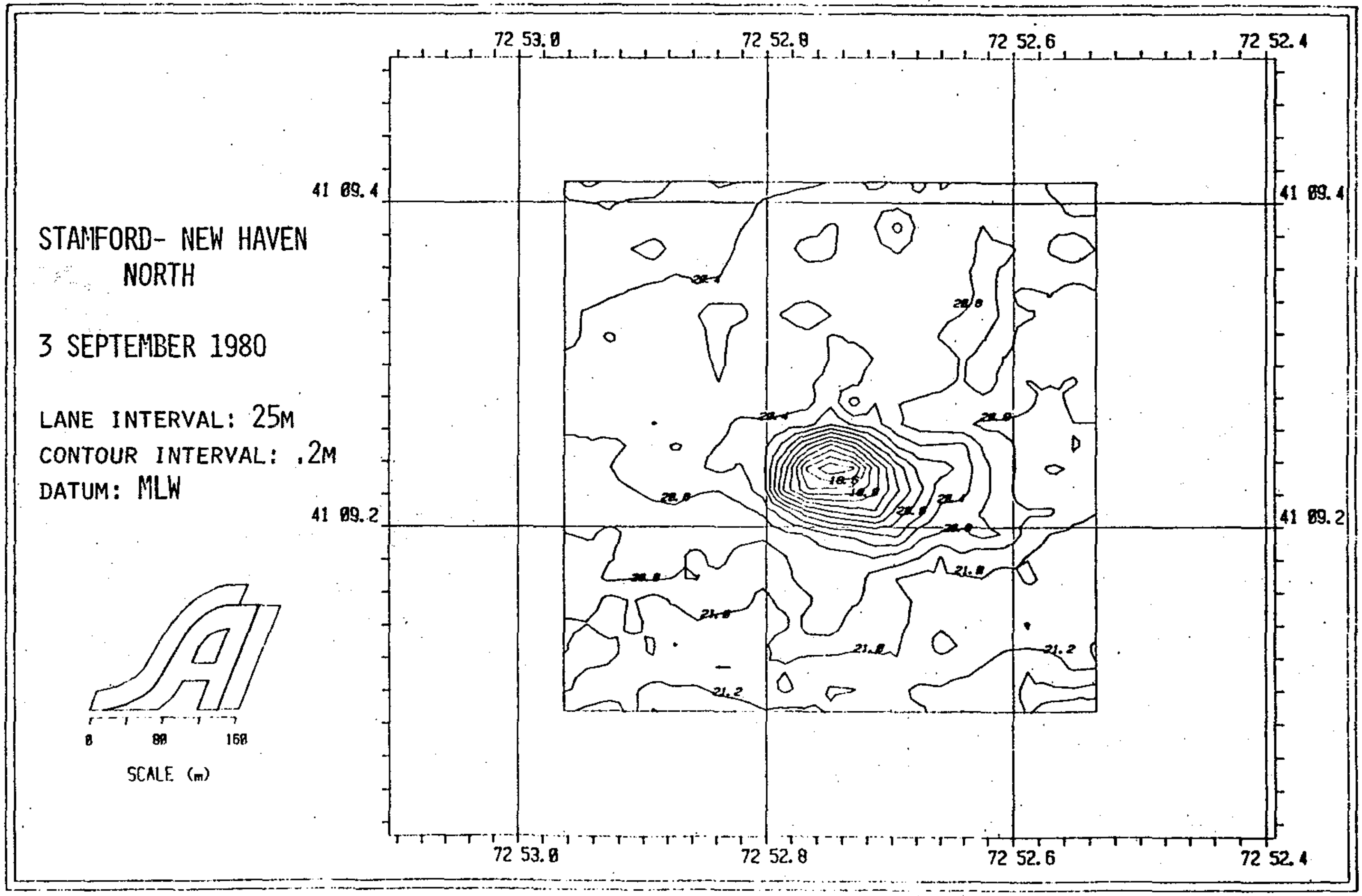

STAMFORD- NEW HAVEN
NORTH
3 SEPTEMBER 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: .2M
DATUM: MLW
0
80
160
SCALE (m)
72 53.0
72 52.8
72 52.6
72 52.4
41 09.4
41 09.2
21.0
21.2

Figure 2.5.2-2

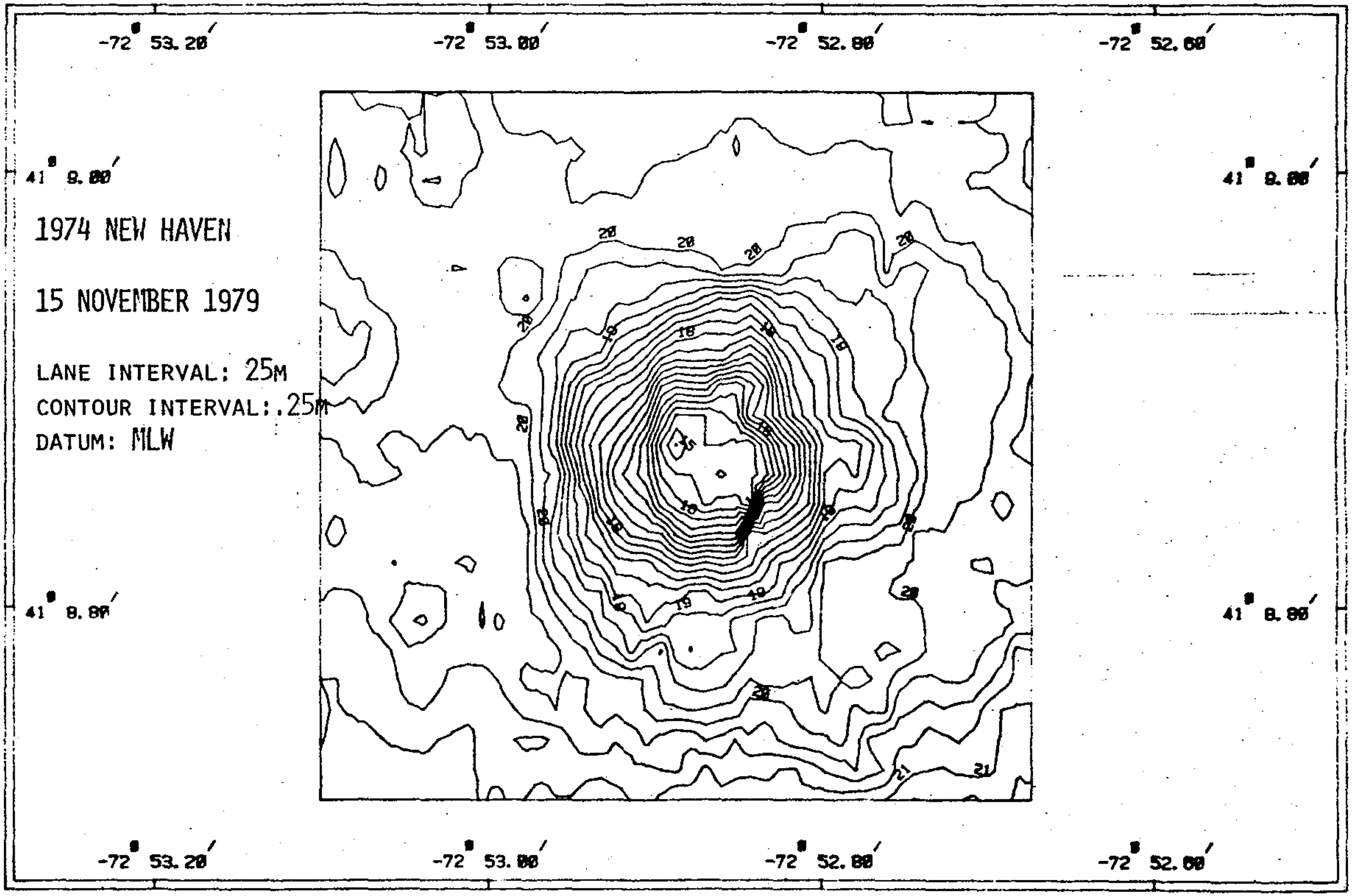

-72° 53.20'
-72° 53.00'
-72° 52.80'
-72° 52.60'
41° 8.80'
1974 NEW HAVEN
15 NOVEMBER 1979
LANE INTERVAL: 25M
CONTOUR INTERVAL: .25M
DATUM: MLW
20
19
18
21

Figure 2.5.3-1

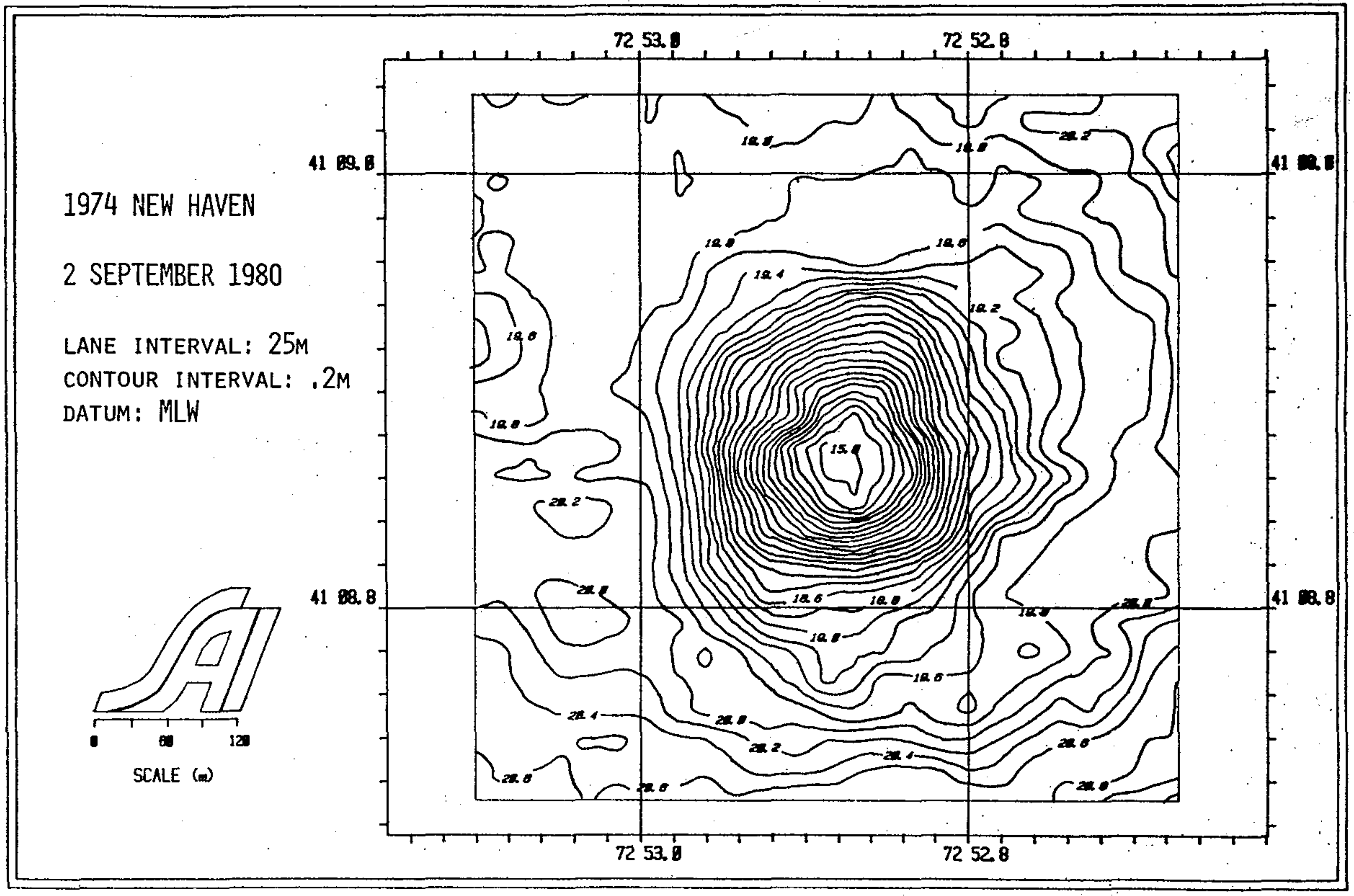

1974 NEW HAVEN
2 SEPTEMBER 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: .2M
DATUM: MLW
0
60
120
SCALE (m)
72 53.0
72 52.0
41 09.0
41 08.0
72 53.0
72 52.0

Figure 2.5.3-2

significant changes in topography have occurred and the mound remains as a stable feature in the Central Long Island Sound Disposal Area.

2.5.4-1 Norwalk Disposal Site

Based on the results of the Stamford-New Haven project a similar capping procedure was proposed for sediment to be dredged from Norwalk Harbor. Although the material from Norwalk was not as heavily contaminated as Stamford sediment, some areas of the harbor contained material which fell under Class III specifications of the State of Connecticut sediment classification scheme. Consequently, a covering operation with cleaner sediment from the same harbor was developed. During 1980, baseline measurements at the disposal site were obtained, a disposal marker was deployed, and some relatively clean material from Norwalk was dumped south of the buoy. The disposal of more contaminated sediment and the subsequent capping operation were not scheduled until 1981.

The Norwalk Disposal Site was established in the Central Long Island Sound Disposal Area at 41° 08.9'N, 72° 53.5'W, approximately 500 m northwest of the "SP" buoy which is located west of the other three disposal points. A baseline survey conducted on April 1, 1980 (Figure 2.5.4-1) indicated that the proposed disposal site was extremely flat at a depth slightly greater than 21 meters. A slight mounding was observed in the vicinity of the "SP" buoy.

Disposal of material south of the buoy continued through June 1980 and a survey was conducted on June 12, 1980 (Figure 2.5.4-2) to determine the distribution of sediment at that time.

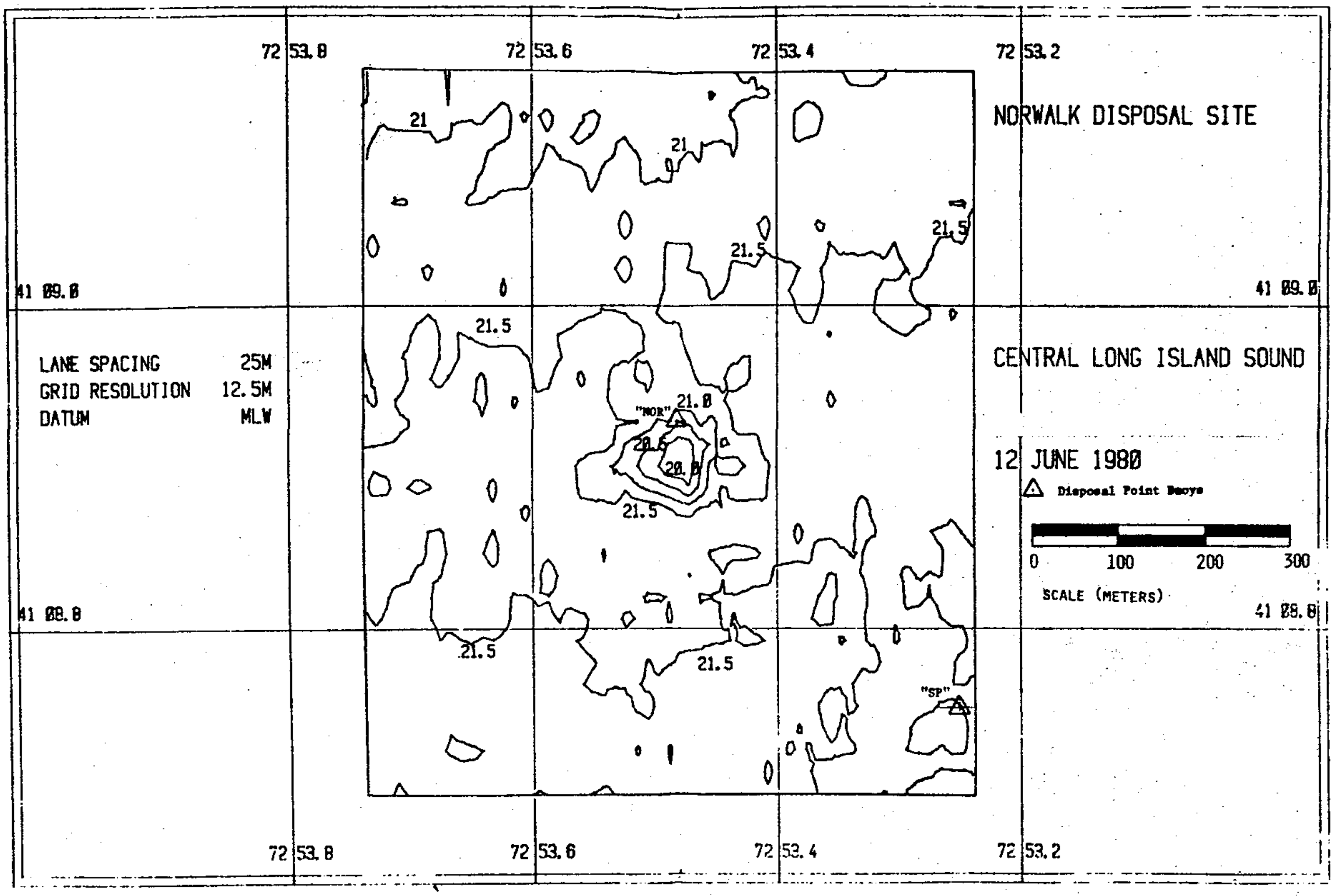

NORWALK DISPOSAL SITE
CENTRAL LONG ISLAND SOUND
12 JUNE 1980
Disposal Point Buoys
LANE SPACING 25M
GRID RESOLUTION 12.5M
DATUM MLW
0 100 200 300
SCALE (METERS)
72 53.8
72 53.6
72 53.4
72 53.2
41 09.0
41 08.0
21
21.5
21.0
20.5
20.0
"NOR"
"SP"

Figure 2.5.4-2

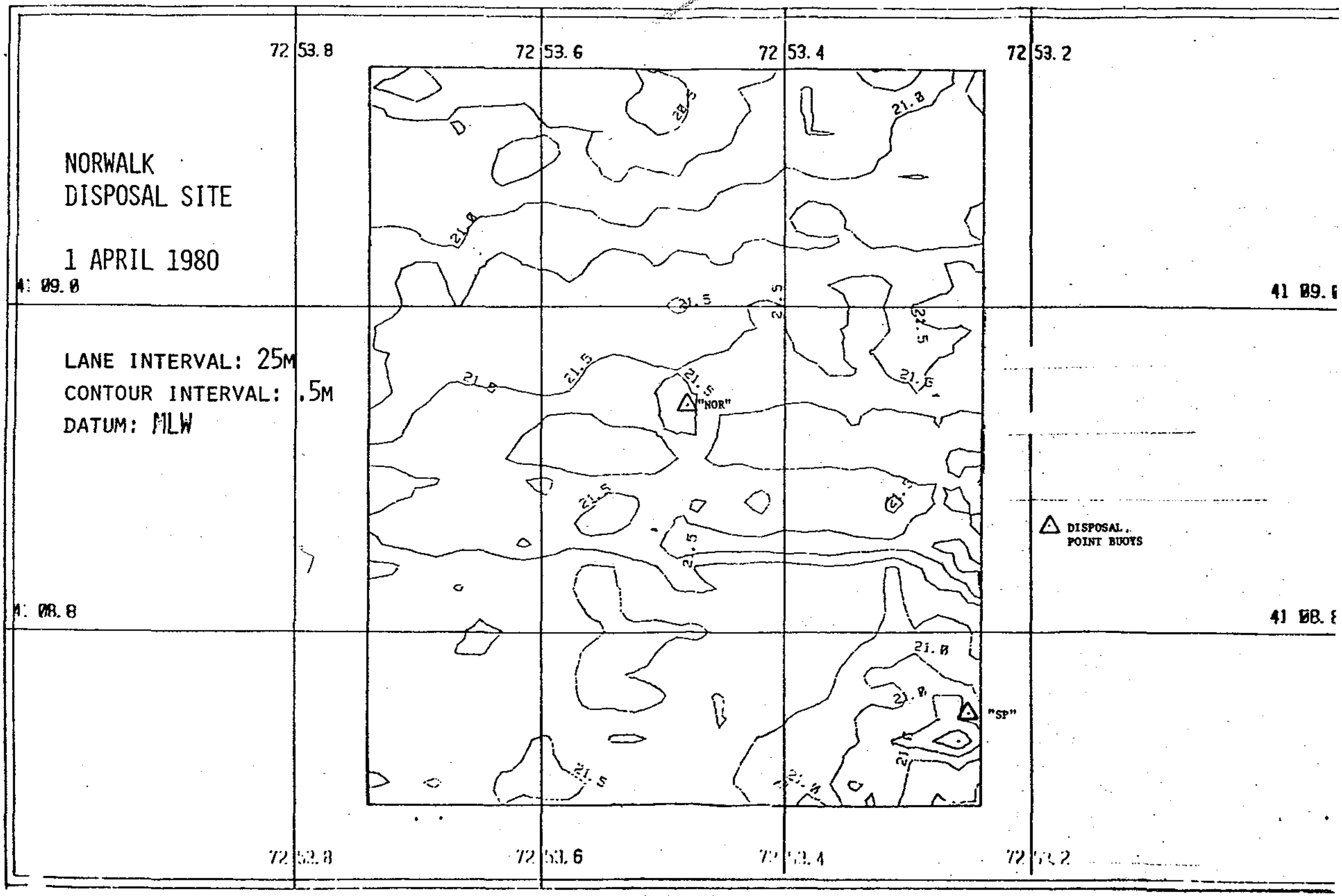

NORWALK
DISPOSAL SITE
1 APRIL 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: .5M
DATUM: MLW
72 53.8
72 53.6
72 53.4
72 53.2
41 09.0
41 08.8
"NOR"
"SP"
DISPOSAL POINT BUOYS
21.5
21.8
21.0

Figure 2.5.4-1

The mound which resulted from this operation was approximately 2 meters thick and 300 meters in diameter. A subsequent survey in September 1980 (Figure 2.5.4-3) indicated that this deposit was stable through the summer, and therefore, continued disposal of Norwalk material should produce similar conditions to those experienced during the Stamford-New Haven project.

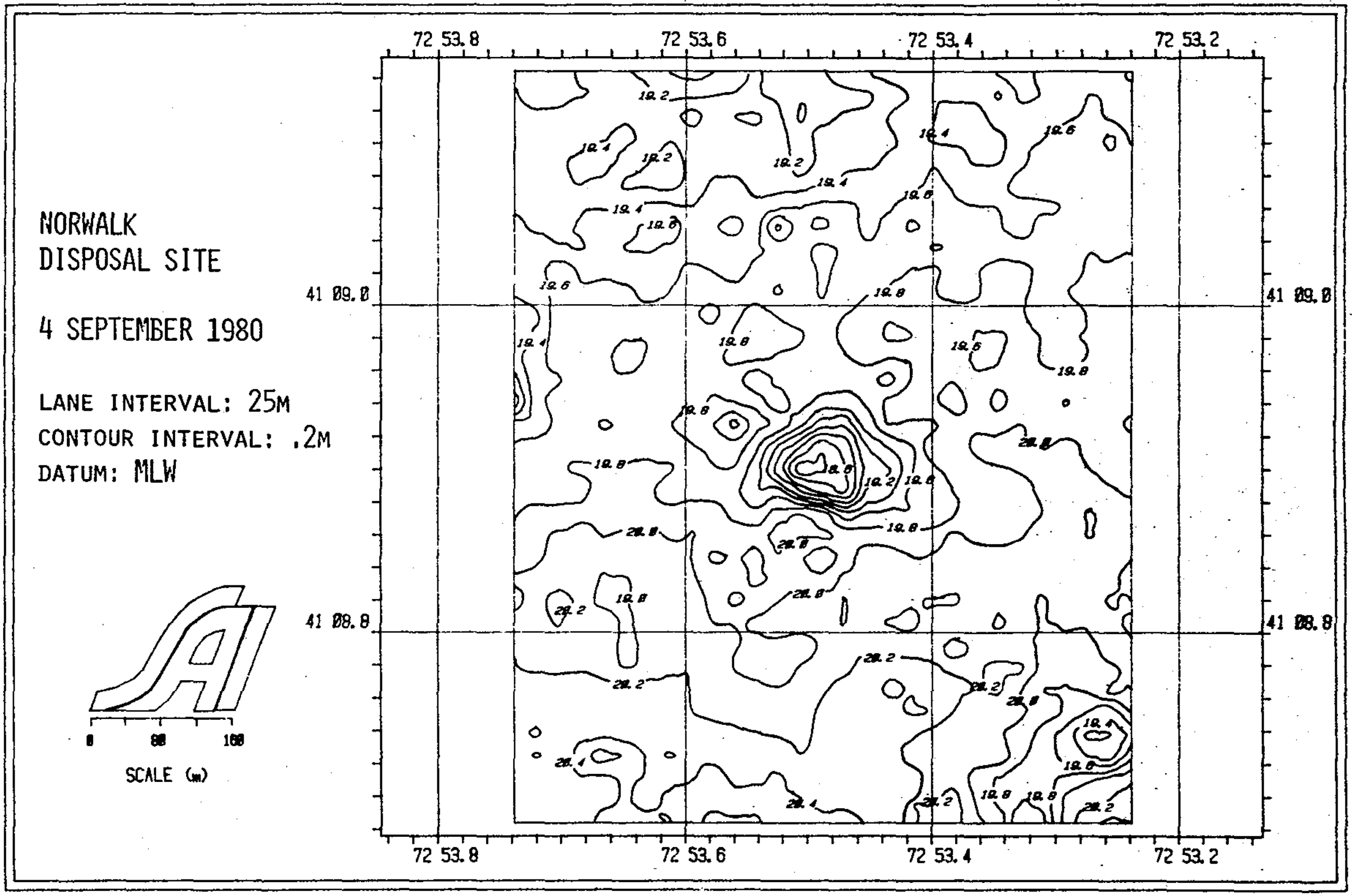

NORWALK
DISPOSAL SITE
4 SEPTEMBER 1980
LANE INTERVAL: 25M
CONTOUR INTERVAL: .2M
DATUM: MLW
SCALE (m)
72 53.8
72 53.6
72 53.4
72 53.2
41 09.0
41 08.8

Figure 2.5.4-3

3.0 STAMFORD-NEW HAVEN BATHYMETRIC MONITORING

3.0 STAMFORD/NEW HAVEN BATHYMETRIC MONITORING

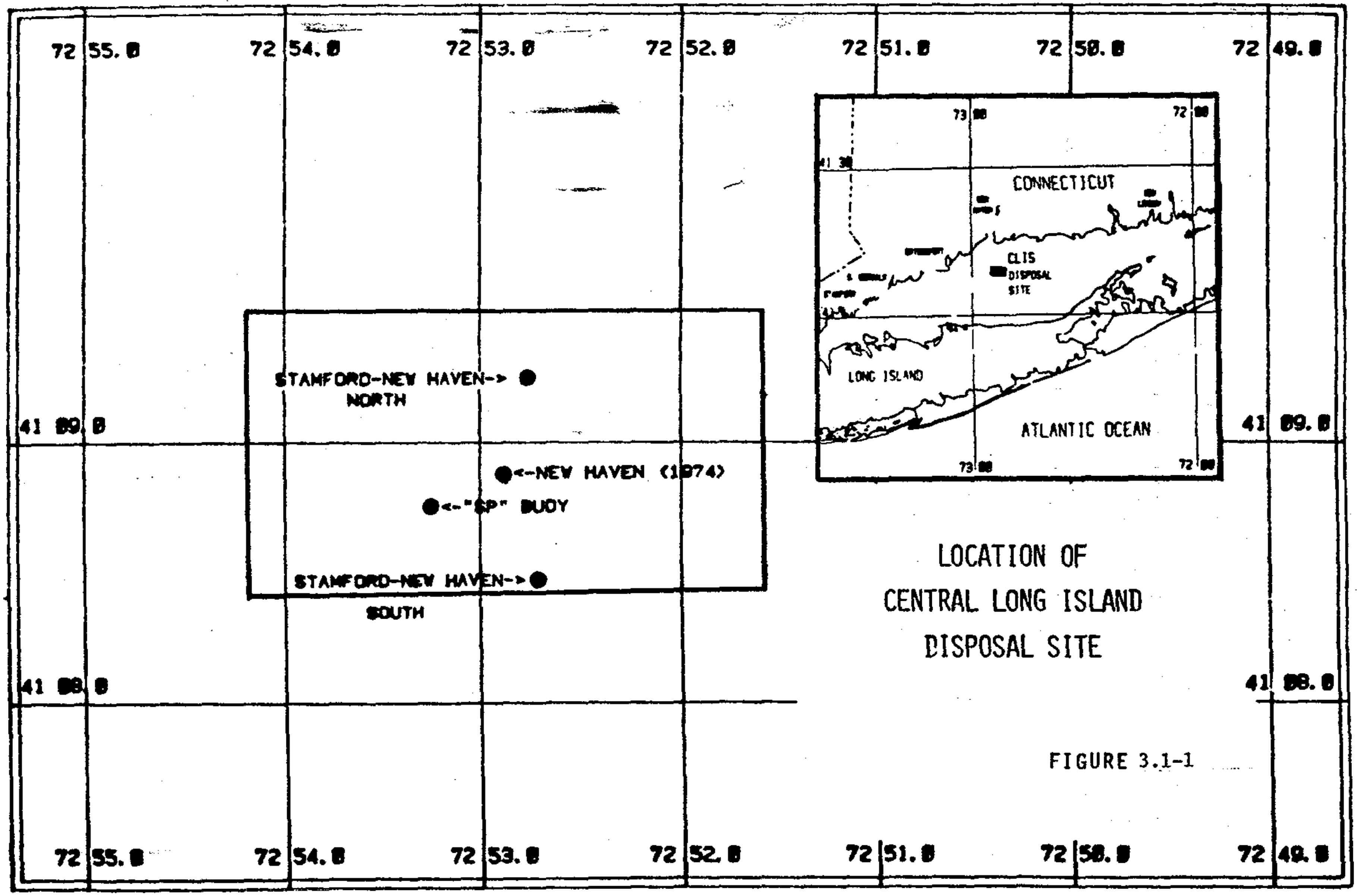
3.1 Introduction

In 1977, the New England Division of the Corps of Engineers undertook a carefully managed and monitored program of disposal at two sites within Long Island Sound. Under this program, dredged materials from the Thames River were deposited at the New London Disposal Site; while sediments from Stamford and New Haven harbors were placed at the Central Long Island Sound Disposal Site (Figure 3.1-1).

Because bulk sediment analyses indicated that dredged material originating from Stamford Harbor was contaminated with heavy metals, management procedures were initiated to "cap" the Stamford material with silt and sand from New Haven Harbor. The objectives of the capping procedures were to isolate the polluted material from the benthic fauna and the overlying water column; to evaluate the relative merits of sand and silt as capping materials in terms of coverage, stability, and effectiveness in isolating contaminants, and to estimate recolonization potential.

Monitoring of the disposal operation was conducted as part of the Disposal Area Monitoring System (DAMOS) and consisted of precision bathymetric mapping of dredged material distribution, visual observations of the disposal mound surface and margins, chemical comparisons of dredged and natural sediment and sampling of benthic populations for recolonization and bioaccumulation studies. This paper is concerned primarily with the results and implications of the bathymetric monitoring procedures.

Replicate precision bathymetric surveys were



LOCATION OF
CENTRAL LONG ISLAND
DISPOSAL SITE

FIGURE 3.1-1

preformed during the disposal and capping operation to monitor the volume and distribution of exposed Stamford material at the disposal site. Following the completion of the capping operation, additional replicate surveys were made to monitor the long-term stability of the capping material.

3.2 Instrumentation and Procedures

Application of bathymetric surveying techniques to monitoring small changes in topography which resulted from either accumulation or loss of dredge spoil material, required that measurements be made with extreme precision. To achieve this precision, a computerized navigation and data acquisiton system was used with carefully controlled range and depth measurement sensors.

This system consisted of a Hewlett Packard 9825A computer and 9872A plotter interfaced with a Del Norte Trisponder system, an EDO 4034A fathometer and an EDO 261C Digitrak unit. The computer and plotter were also used to obtain report quality charts of bathymetric data within a short time after completion of a survey. Data quality was assured by a careful calibration program to provide accurate measurements of range and depth. All shore stations were surveyed to an accuracy of $\pm$10 m, and the fathometer was calibrated with a bar check prior to each survey.

Since a computer was used for data acquisition, all corrections for ships draft, sound velocity and tidal height were made after completion of the survey and all adjustments on the fathometer were set to zero.

Earlier measurements of tidal height at the Central Long

Island Sound Disposal Site have indicated close agreement with predicted tidal heights under ambient weather conditions. Since this relationship was previously established and because additional corrections were applied that reduce tidal errors in the survey data, predicted tidal correction values were used for all surveys in this study.

Prior to the disposal of dredge material at this site, a survey grid was established (Figure 3.2-1) consisting of 25 transects, 600 m long oriented in the east-west direction and spaced 25 m apart. While conducting the survey, range data were input to the computer which provided steering information to assist the helmsman in maintaining the ship's position relative to the survey grid. Since precision data were required for this work, surveys were only made on calm days and the errors in steering the ship were generally less than 5 meters either side of a given transect (Figure 3.2-1). This navigational precision was necessary for comparing replicate surveys since slight errors in position can cause large errors in depth over sloping bottoms.

Data acquisition was controlled by the sampling rate of the Del Norte Trisponder unit which was nominally one range measurement per second. Depths were averaged over this one second interval and recorded on cassette tape with corresponding time and position information.

Analysis of bathymetric data was first accomplished through the generation of depth sections along the transect lanes. Since each transect was reproducible with a positional accuracy of better than 5 meters, these sections provide a means of evaluating the precision of the survey technique as well as small scale

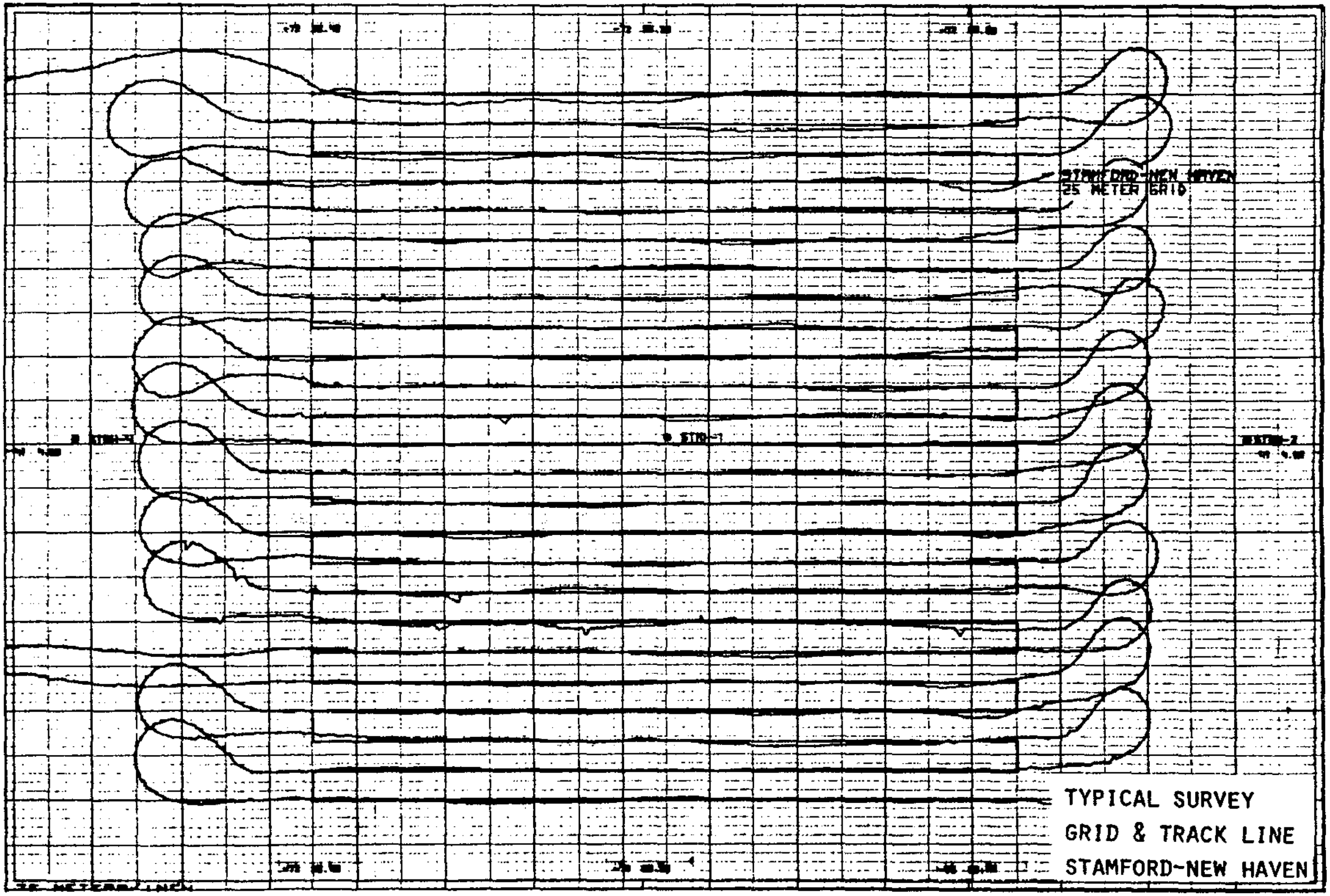

STAMFORD-NEW HAVEN
25 METER GRID
TYPICAL SURVEY
GRID & TRACK LINE
STAMFORD-NEW HAVEN

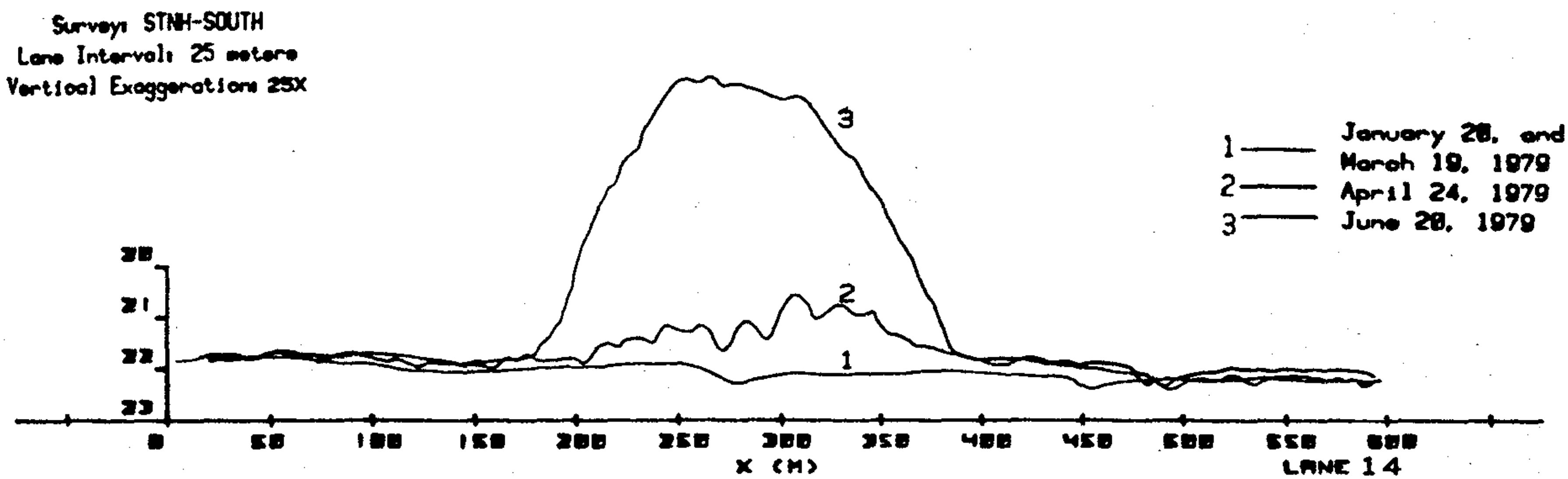
FIGURE 3.2-1

changes in topography. All depths on these sections were corrected for sound velocity, draft and tidal height.

Figure 3.2-2 presents a section of a representative transect across the spoil mound at the southern New Haven disposal site. Assuming no significant change (i.e. deposition or erosion) in the depth of the ambient bottom at some distance from the spoil mound, the precision of the depth measurements between successive surveys can be evaluated by comparing the depths at the extremeties of the transect. In Figure 3.2-2, it is apparent that there are no significant depth differences beyond the disposal mound between sequential surveys at this site.

Following the development of the vertical sections, the data were inserted into a grid pattern for further analysis. This grid pattern was established such that each grid block was centered on a transect lane, had a north-south length equal to the lane spacing (25 m) and an east-west length equal to one half the lane spacing (12.5 m). This convention was applied to all surveys even though it was possible to establish a finer grid pattern by sampling more frequently along the transect direction. The finer grid pattern would, however, introduce a bias into the data since the resolution between lanes cannot be improved.

All depth measurements falling within the area of each grid block were averaged and a mean depth was assigned to each grid location. The matrix of depths was then used to develop a contour chart of the entire survey area. Contour intervals of .25 meters were drawn on all charts of the Central Long Island Sound Disposal Site.



PRECISION OF DEPTH MEASUREMENTS
OBTAINED ON REPLICATE SURVEYS

FIGURE 3.2-2

Calculations of volume difference between successive surveys could also be accomplished by comparison of the grid data. The difference in depth (ΔZ_i) of each cell between successive surveys was determined by subtraction and then multiplied by the area of the cell to determine the net change in volume. These volume changes were then summed along transects and over the entire grid to determine the total volume change.

The precision of the depth measurement had to be extremely high to achieve an accurate volume because small changes in depth were multiplied by the area of the survey. In order to increase this precision, additional corrections were made based on the assumption that no significant changes in depth occur on the natural bottom beyond the extremeties of the disposal mound. This assumption was fully supported by the data presented in Figure 3.2-2. To make these corrections the average depth changes (ΔZ_i) for all grid locations in the first and last five lanes were determined. If these (ΔZ_i) were different from zero a correction was applied to the third and twenty-third lanes to set those differences to zero. Correction factors for each transect were then determined by linear interpolation between adjacent lanes.

Small differences resulting from errors in tide, sound velocity or draft corrections were thus accounted for and the baselines of both surveys were accurately aligned with each other. Corrections of this type, while always less than 10 cm, were important for increasing the resolution of the volume difference technique.

The errors in determining the topographic volume relative to a baseline were evaluated through a calculation of the standard error based on the standard deviation of the depth measurement. A conservative estimate of the precision in depth measurement by echo sounding which accounts for navigation, correction factors, topographic changes etc. is ±20 cm.

Using this figure for the standard deviation of all depths measured within a grid cell, the standard error for a given cell was

$$\epsilon_i = \frac{\sigma_i}{\sqrt{n_i - 1}}$$

where n_i is the number of measurements in the cell.
For the entire survey, the average depth was calculated by

$$\overline{Z} = \frac{1}{M}\sum_{i=1}^{M} \overline{Z}_i$$

where M is the number of cells
Therefore, the standard deviation of ($\overline{Z}$) resulting from errors in the depth measurement can be expressed as

$$\sigma_{\overline{z}}^2 = \frac{1}{M^2}\sum_{i=1}^{M} \overline{\epsilon}_i^2$$

$$\sigma_z^2 = \frac{1}{M}\overline{\epsilon}_i^2$$

$$\sigma_z = \frac{\sqrt{\overline{\epsilon}_i^2}}{\sqrt{M}}$$

Since the volume difference approach was used for this computation, the calculation was actually made on the amount of water over the site and the difference could be expressed as

$$\Delta V = A\overline{Z}_1 - A\overline{Z}_2$$

Therefore, the standard error of the volume calculation for each survey is

$$\epsilon_v = A\sigma_{\bar{z}} = \frac{A\sqrt{\bar{\epsilon}_i^2}}{\sqrt{M}}$$

Assuming that the standard deviations of all cells were approximately equal, this equation reduced to

$$\epsilon_v = \frac{A\sigma_i}{\sqrt{M(n-1)}}$$

and for each New Haven survey

$A = 600 \times 600 = 3.6 \times 10^5 m^2$

$M = 48 \times 25 = 1200$

$\sigma_i = 0.2m$

therefore,

$\epsilon_v = 1200m^3$

Since two surveys were required to accomplish a volume difference calculation, the total error could be as much as 2400 m^3.

Since a depth difference (Δz_i), between succesive surveys, was determined for each grid cell, a contour program was applied to the difference data and a contour difference plot was generated. This chart provided information on the distribution of changes in depth resulting from the accumulation or loss of material. A contour interval of .2 meters was used on these charts with consistent results due to the correction procedures described above.

These techniques were applied to the monitoring of disposal operations at the Central Long Island Sound site from January to June, 1979, and to post disposal conditions through November 1979. The data obtained during this study represent a significant improvement over previous disposal monitoring efforts for several reasons, including: 1) use of precision navigation control to maintain 25 m lane spacing, 2) the nearly flat bottom available to provide a baseline datum, 3) the application of computer software to complete data sets to provide better calibration between surveys, and 4) the careful management of the disposal operation in order to create a discrete disposal mound which could be evaluated for small topographic changes.

Whether or not these conditions can be duplicated in other areas will be seen in the future, however, this study provided a unique opportunity to accurately measure spoil volumes and to evaluate the importance of such parameters as compaction, stability and capping.

3.3 Management of Disposal Operations

As described earlier, there were two major objectives to be achieved through disposal of dredged material at the Central Long Island Site. These were: 1) containment and isolation of Stamford dredged material by capping with New Haven sediment; and 2) a general evaluation of the viability of the procedure with particular emphasis on the effectiveness of sand versus silt as a capping material. In order to compare the sand and silt caps, two disposal points were designated 1000 m north and south of the mound created by the New Haven project in 1974 (Figure 3.1-1). The south site was designated for capping with silt from the inner harbor and the north site with sand from the outer breakwater area of New Haven Harbor. The north-south orientation was selected since tidal flow through the site is in an east-west direction, thus potential effects resulting from the older mound would be minimized.

Precision disposal of Stamford material was essential in order to create discrete piles prior to capping. To accomplish this, two taut-wire moored buoys were installed at the designated disposal points using the trisponder system for navigation control. Towboat operators were then instructed to dispose of material near the south side of each buoy. Even under adverse conditions disposal generally took place within 25 m of the designated point.

Initial disposal of Stamford material took place between March 25 and April 22, 1979 at the southern disposal point. After April 23, silt from New Haven was dumped at the south site to provide capping material. This continued until June 15 when dredging was halted to avoid impact to oyster larvae by siltation generated from the dredging operation. Disposal of Stamford material was restricted to the north site from April 23 until June 15 when dredging of Stamford Harbor and associated disposal at the north site was halted. Between June 15 and June 21, the hopper dredge ESSAYONS removed sandy sediment from the mouth of the New Haven harbor and used this material to cap the north site.

3.4 Bathymetric Monitoring Procedures

A grid similar to that shown in Figure 3.2-1 was established at both the north and south disposal sites with the disposal buoy centered in the 600 m^2 survey area. Prior to disposal, background surveys were run on these tracks. Two baseline surveys were made at the south site on January 20 and March 19, 1979, and a single survey was made at the north site on March 22. An estimate of the precision of the volume calculation technique was made by comparing the difference between the two southern surveys. This volume difference was approximately 2700 m^3 which is only marginally greater than the error expected from theoretical considerations. Furthermore, the contour difference chart generated from the two surveys indicated that the errors were small and randomly distributed since all contours were either $\pm$0.2m or zero and showed no consistent pattern over the survey area.

Disposal of dredge material from Stamford Harbor at the southern site reached a total of 37,800 m^3 (based on scow load records) on April 22, 1979. A survey of the site was conducted on April 24, to determine the distribution of spoil material prior to capping (Figure 3.4-1). This survey indicated that the disposal procedure was successful in developing a small, discrete mound approximately 100 m in diameter and 1.25 m thick.

Close examination of the vertical depth sections for lanes 13-16 (Figure 3.4-2) indicates that the topography of this mound was quite variable, and thicknesses of 2 meters relative to the initial bottom are present. It is important to note that contouring, by its nature, will smooth and decrease the

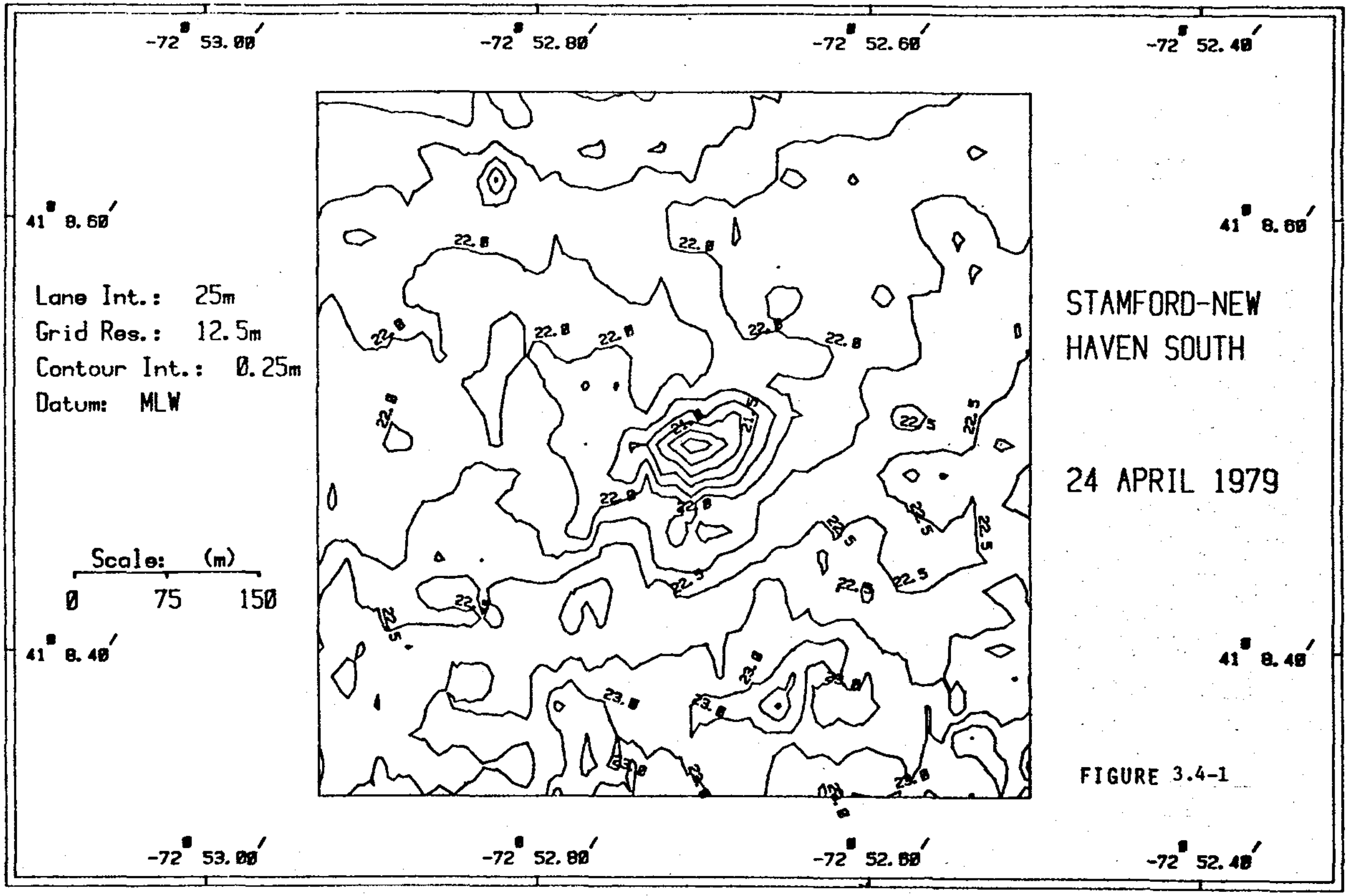

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
STAMFORD-NEW HAVEN SOUTH
24 APRIL 1979
22.0
22.5
23.0

FIGURE 3.4-1

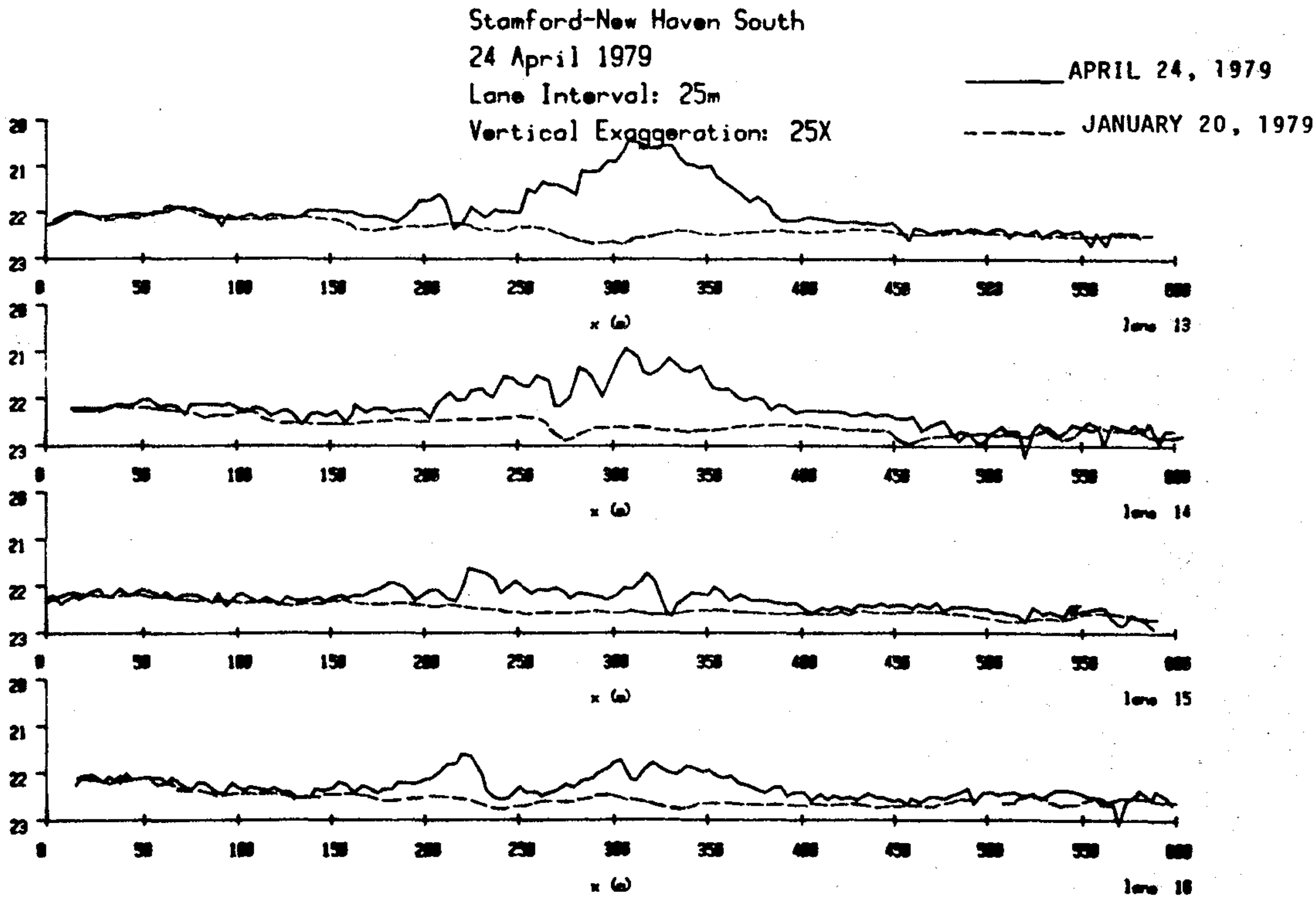


FIGURE 3.4-2

DEPTH PROFILES STNH SOUTH, LANES 13 - 16
APRIL AND JANUARY 1979

topographic expression of the mound. While overall volumes are accurate due to averaging of all depths measured, specific features smaller than the grid size cannot be accurately resolved. These features can, however, be assessed in the vertical profiles, but only within the accuracy of navigation between successive surveys.

The rough topography exhibited in the vertical sections was substantiated by diving observations and attributed to the cohesive nature of the dredged material. Toward the margins of the mound, specific scow loads could be identified as separate topographic features.

Calculations of total Stamford sediment detected relative to the January baseline survey (Figure 3.4-3), resulted in a volume of 35,700 m^3 or approximately 90% of the estimated volume deposited. The contour difference chart (Figure 3.4-4) indicated that there was additional material present beyond the immediate mound, and that it was possible for significant amounts of dredged material to be undetected by acoustic measurements.

This problem was addressed through a combination of visual diver observations and precision (50 m spacing) remote sampling of the fringes of the mound with a Smith-McIntyre grab. During the period of disposal, an extensive population of the stalked hydroid <u>Corymorpha</u> was growing over the entire bottom. Whenever dredge material was present to any significant degree, these hydroids were covered or destroyed. Consequently, the boundary of the Stamford sediment could be readily defined by the presence or absence of these animals. Furthermore, the dark,

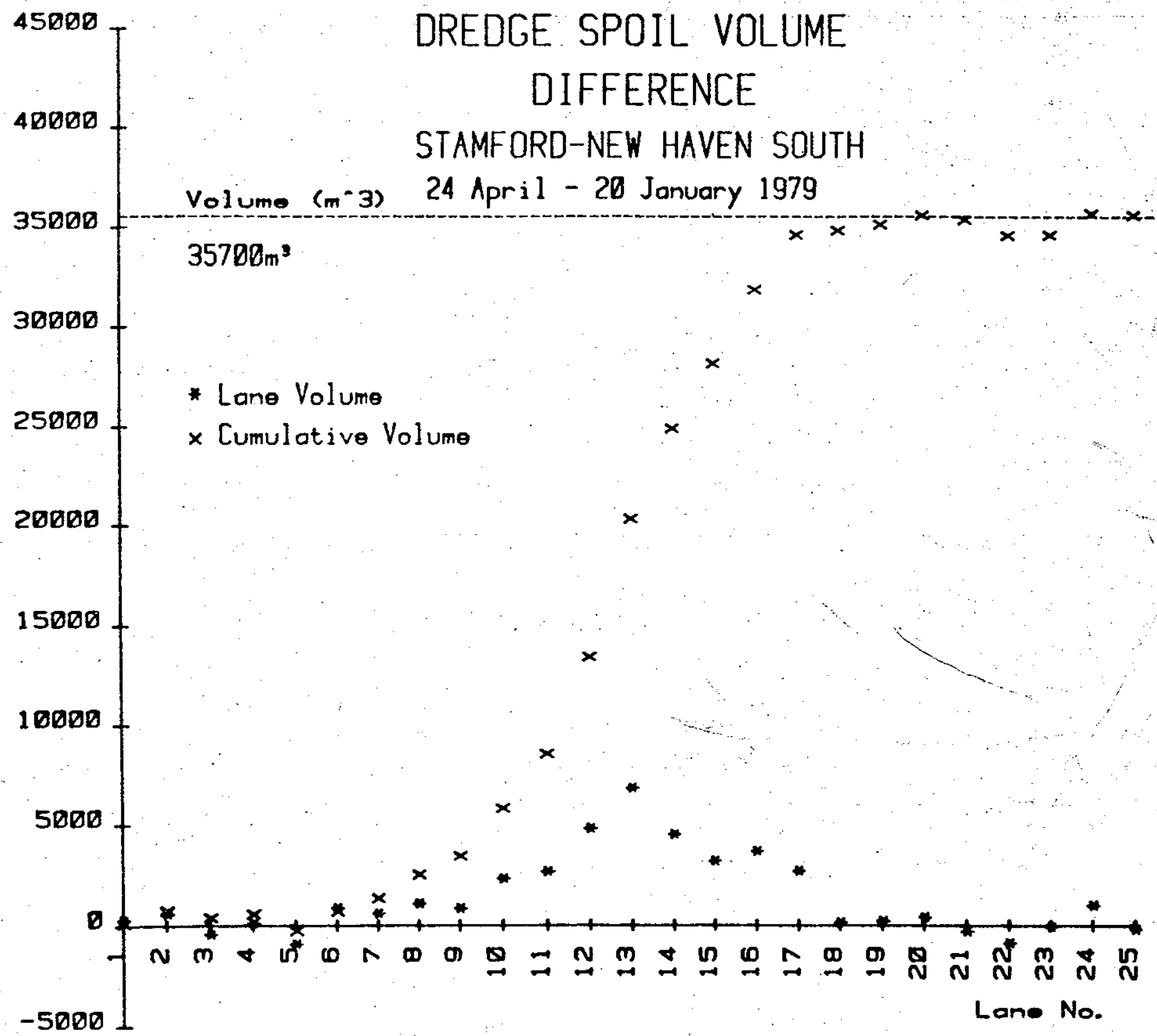
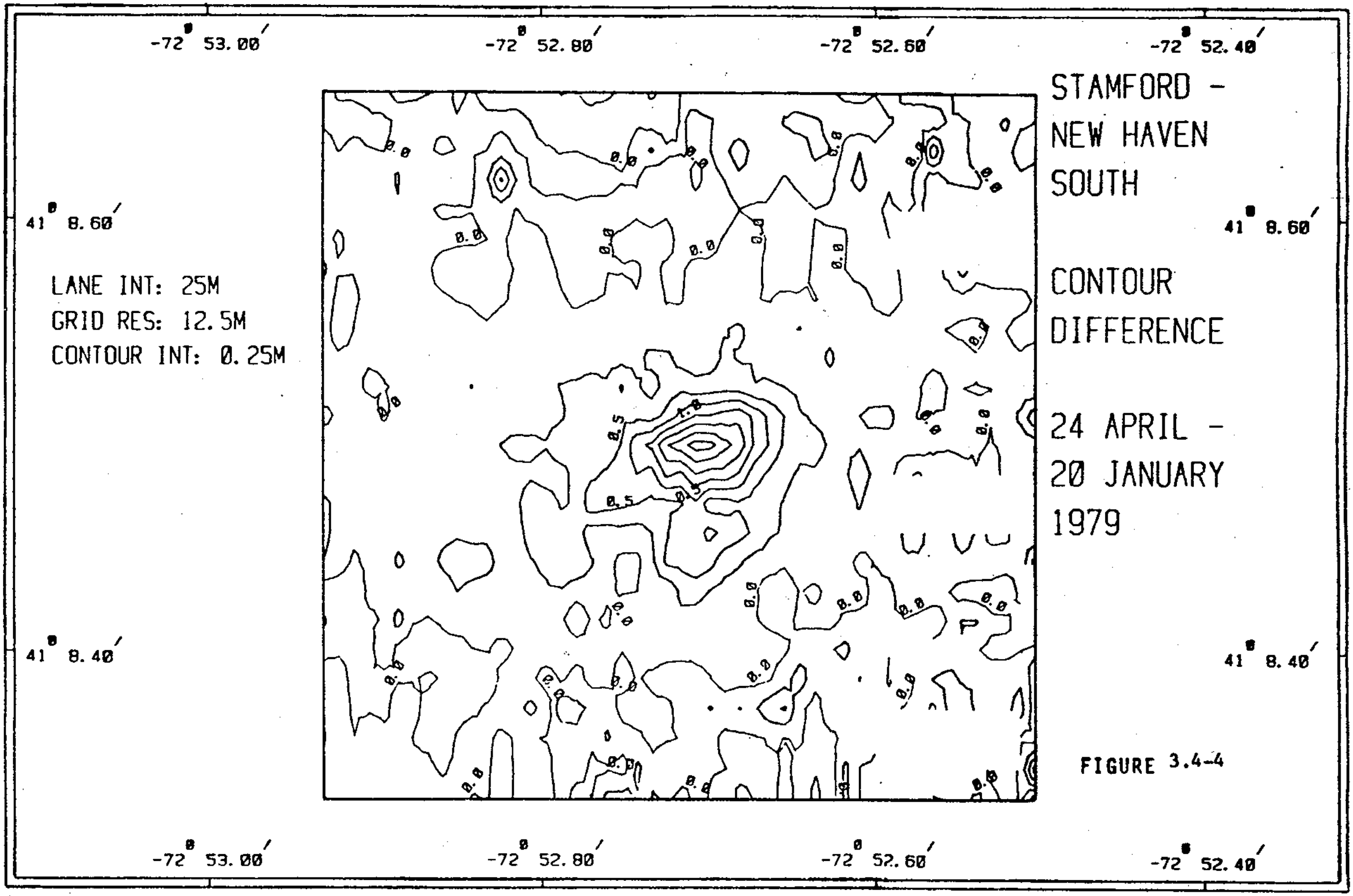

DREDGE SPOIL VOLUME
DIFFERENCE
STAMFORD-NEW HAVEN SOUTH
24 April - 20 January 1979
Volume (m^3)
35700m³
* Lane Volume
× Cumulative Volume
Lane No.
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

FIGURE 3.4-3



-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
STAMFORD - NEW HAVEN SOUTH
CONTOUR DIFFERENCE
24 APRIL - 20 JANUARY 1979
LANE INT: 25M
GRID RES: 12.5M
CONTOUR INT: 0.25M

FIGURE 3.4-4

organic dredged material provided a sharp contrast to the natural, brown oxidized muds of the disposal site so that the thickness of the margins of the mound could be directly measured in the grab sampler.

The most striking result of these measurements was the rapid decrease in dredged material thickness at the margins of the mound. In the east and west directions, the change from thickness greater than 50 cm to less than 5 cm occurred between 100 and 150 m from the disposal point. In the north-south direction, the change occured between 50 and 100 m. It was apparent that the cohesive nature of the dredged material was creating a definite mound with discernable boundaries that could be acoustically detected with spatial accuracy certainly better than 50 m.

Volume calculations along the periphery of the mound were made by assuming that beyond the immediate disposal point the material flowed uniformly outward and was, therefore, of uniform thickness at a given radius from the center of the mound. This assumption was supported by the observation that the coarseness of the particles in the fringe areas decrease inversely with distance from the disposal point. The evidence indicated that when cohesive sediments are dredged and dumped in shallow water on a flat bottom, approximately 80% of the sediment is transferred to the bottom as a cohesive unit and forms a mound, while most of the remaining material forms a turbidite type deposit spreading radially from the disposal point.

The volume of dredged material in the fringe area was estimated by contouring the measured thickness in the grab sample and measuring the major and minor axes of the resulting ellipse.

The area of each ellipse was multiplied by the difference thickness and summed to calculate the total volume. This volume measured 1980 m^3 or approximately 5% of the estimated disposed dredge material.

Since the bathymetric and sampling procedures accounted for more than 95% of the estimated material dumped at the site and since the error of estimating volume in the scows must be relatively large, it was concluded that the bathymetric survey technique was adequate for monitoring disposal operations. Furthermore, these data indicated that the initial disposal of Stamford material was tightly controlled by the taut-wire buoy and subsequent capping with New Haven material should be successful. Disposal of additional Stamford material at the north site was also accomplished successfully and a monitoring survey conducted on 21 May (Figure 3.4-5) indicated the development of a small mound similar to that observed at the south site. 26,000 m^3 of Stamford material were deposited at this location prior to capping.

As described earlier, silt from New Haven Harbor was dumped on the Stamford material at the south site and sand from the breakwater area was used to cap the northern site. Capping was completed on June 15 at the south site and on June 22 at the north site. On June 20, a survey was made of the southern site (Figure 3.4-6) to determine the success of the silt capping operation. The contour chart and the depth sections (Figure 3.4.7 indicated that a distinct mound had developed with a minimum water depth of 16 m and a thickness of up to 4 meters over the Stamford sediment. Because the silt material from New Haven was

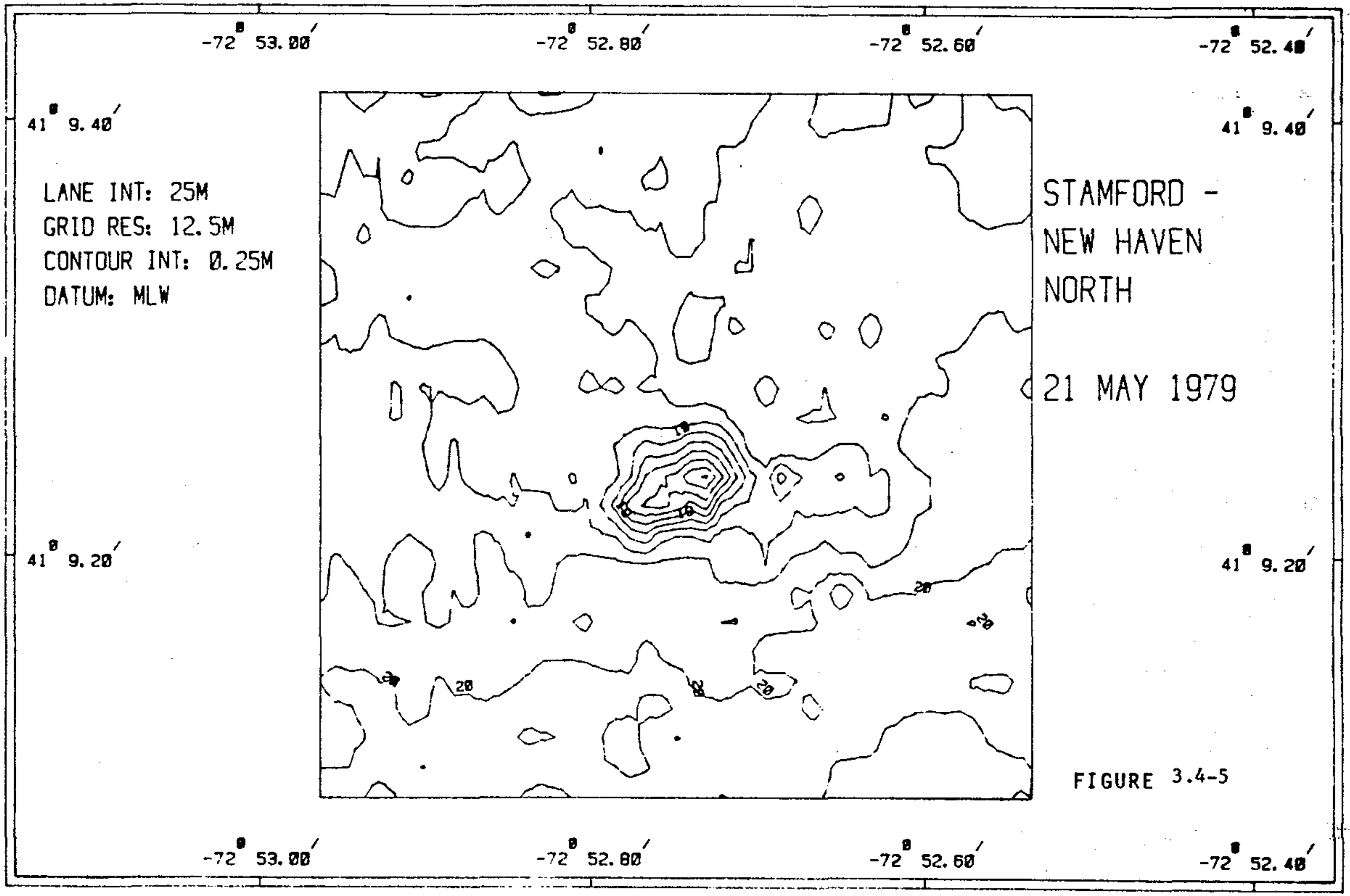

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
LANE INT: 25M
GRID RES: 12.5M
CONTOUR INT: 0.25M
DATUM: MLW
STAMFORD -
NEW HAVEN
NORTH
21 MAY 1979
20

FIGURE 3.4-5

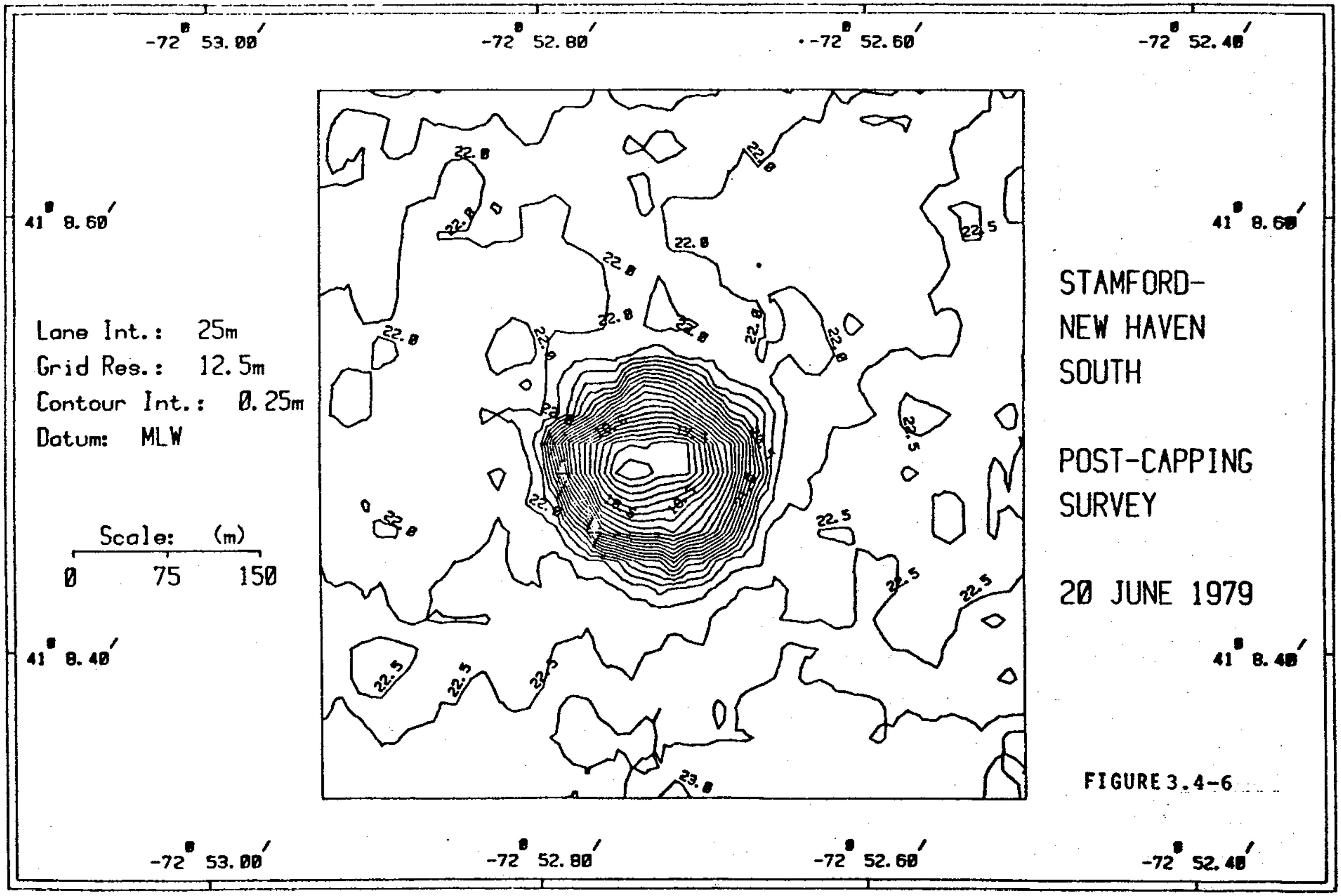
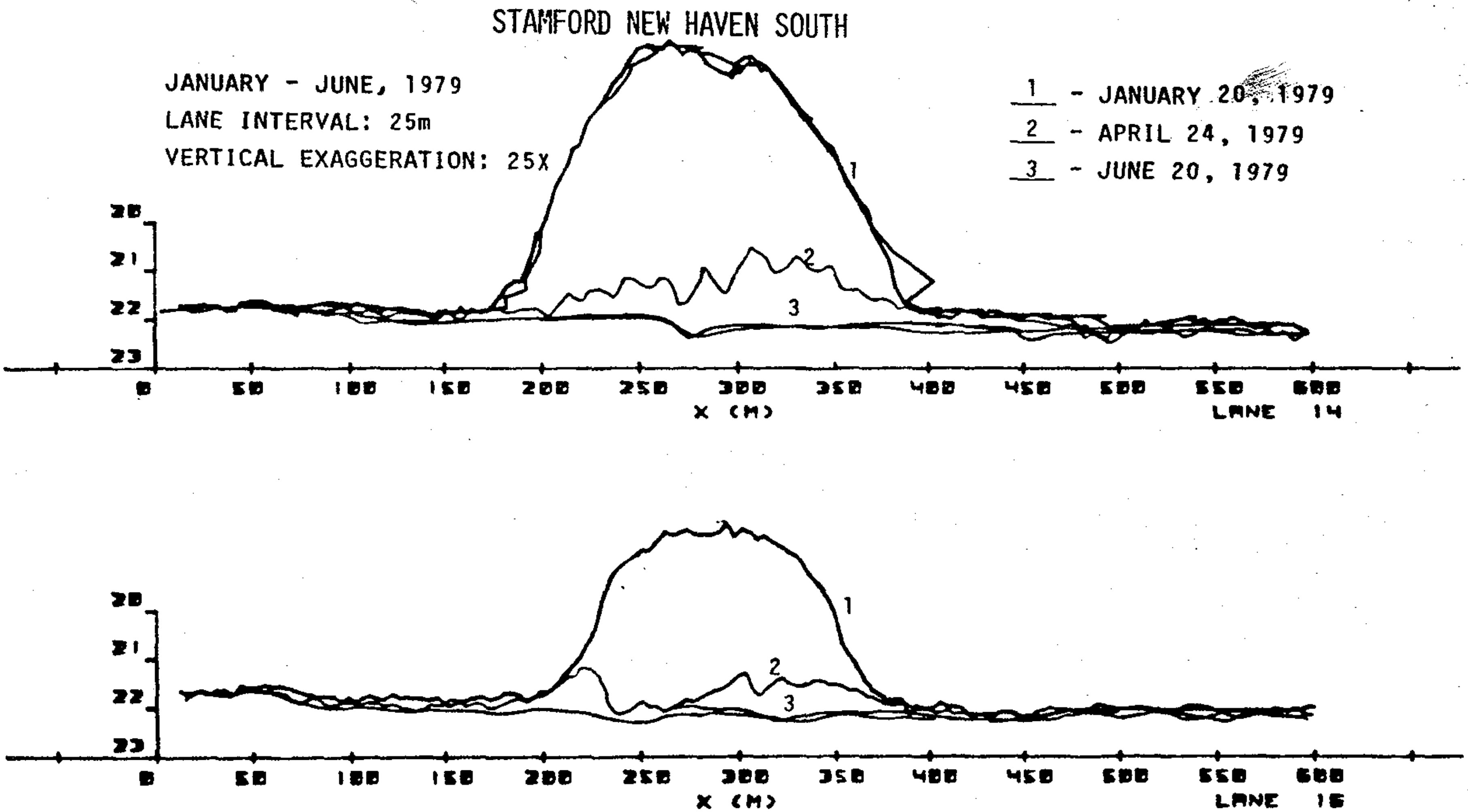

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
22.0
22.5
23.0
STAMFORD-
NEW HAVEN
SOUTH
POST-CAPPING
SURVEY
20 JUNE 1979

FIGURE 3.4-6



DEPTH PROFILES STNH SOUTH, LANES 14 & 16

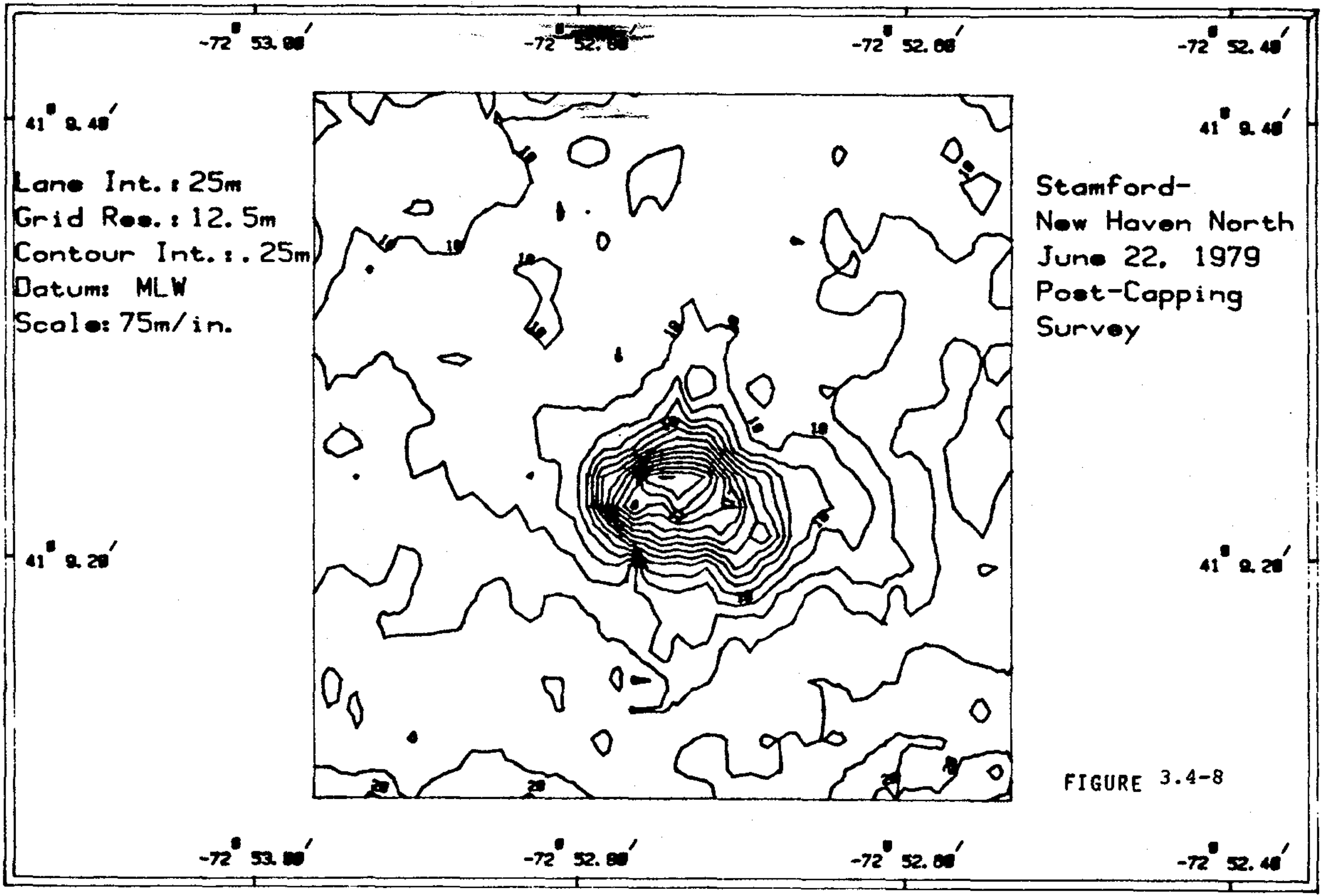
JANUARY & JUNE 1979

FIGURE 3.4-7

cohesive, the resulting mound did not display extensive spreading. Although the sections indicated that all Stamford material was capped, future operations with silt should be designed to spread the capping sediment and reduce the thickness to some extent. The volume of New Haven sediment dumped as capping material at the south site was estimated at 76000 m^3 from scow load measurements, of which 72000 m^3, or 95%, was accounted for by volume calculations.

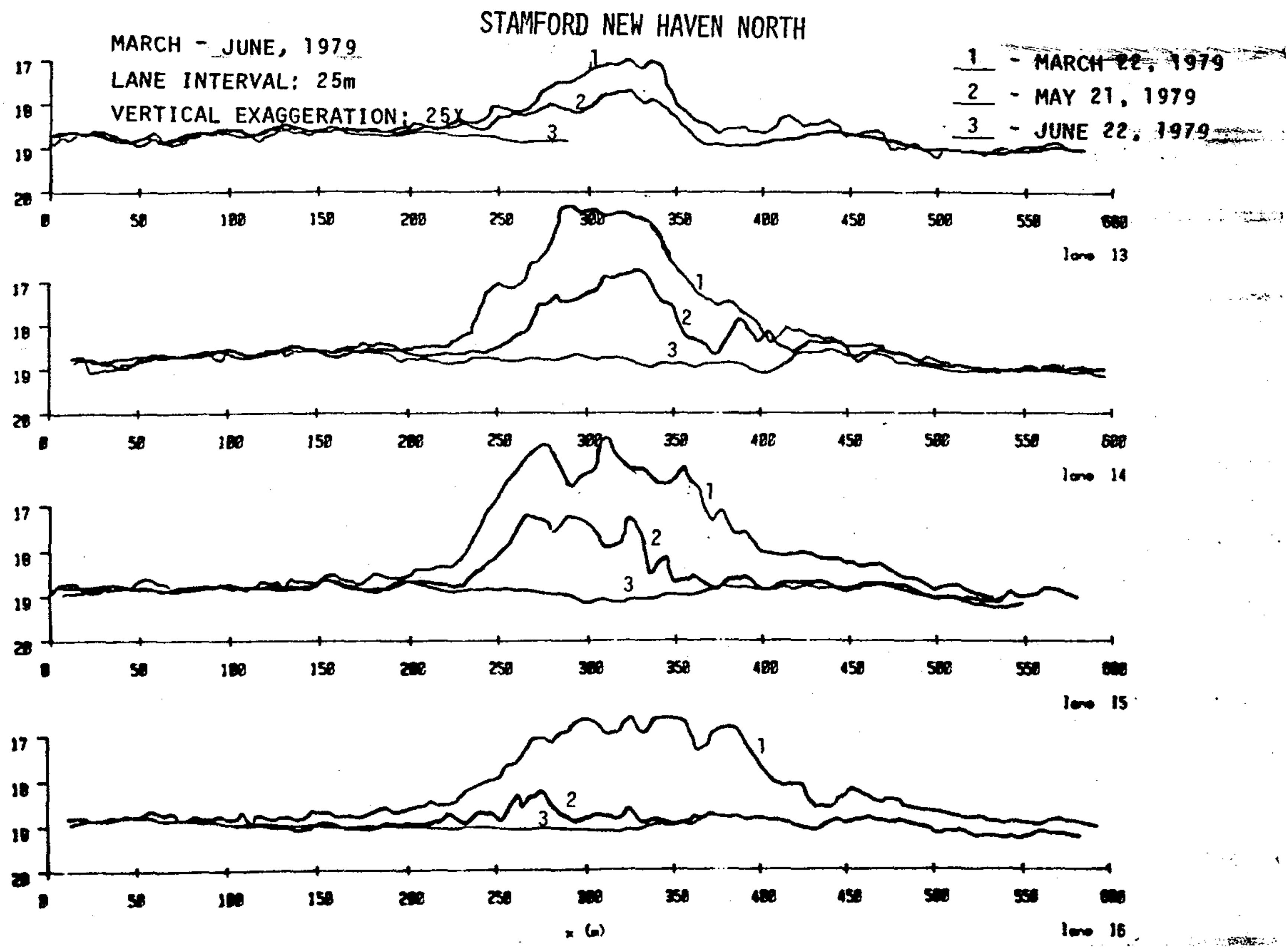
Capping of Stamford material at the northern disposal site was accomplished in six days using the hopper dredge ESSAYONS to create a sand layer. Management of this operation was aided by a bathymetry survey on June 19, to determine any areas that were not covered by sand, and the dredge was directed to dump additional material east of the disposal buoy to insure complete coverage. A final survey was conducted on June 22, after completion of the capping operation (Figure 3.4-8). This survey and the associated sections (Figure 3.4-9) indicated that all Stamford sediments were capped by the sand material. However, since the sand was less cohesive, it tended to flow during deposition thus creating a broader, flatter mound than that developed by silt at the southern site.

At the time of the June 22 survey the capping layer had a maximum thickness of 3.5 meters over the Stamford material. This cap was a smooth blanket of sand that divers were unable to penetrate more than 10-15cm by digging with their hands. A calculation of the volume of sediments deposited since the May 21 survey indicated an increase of 33,000 m^3. This volume compared favorably with dredge volumes specified by the ESSAYONS. However,



-72° 53.00′
-72° 52.80′
-72° 52.60′
-72° 52.40′
41° 9.40′
41° 9.20′
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in.
Stamford-
New Haven North
June 22, 1979
Post-Capping
Survey
10
20

FIGURE 3.4-8



DEPTH PROFILES STNH NORTH, LANES 13 - 16
MARCH - JUNE 1979

FIGURE 3.4-9

large correction factors based on density and water content of the sand, make comparisons tenuous and calculations of volume and percentage lost to the water column meaningless.

The results of these surveys indicate that the capping procedures employed during the Stamford New Haven disposal operation were successful. The precision disposal of Stamford sediment resulted in two small compact mounds that were readily covered with New Haven material. There was little apparent difference in the ability of sand or silt to accomplish the desired capping. In the case of sand, the capping layer was not as thick, but the smooth, dense nature of the deposit should act as a tough, impervious blanket over the original dredged material. Silt deposits on the other hand, derive their capping ability from the cohesive nature of the sediment, developing a thicker deposit with rougher micro-topography. Several recommendations for future capping operations can be made based on the data obtained from this study:

- The cohesive nature of the dredged material to be covered must be maintained in order to reduce its spatial scatter. This would normally be the case since higher concentrations of contaminants are generally found in fine grained cohesive sediments. However, dredging procedures must be conducted in a manner to preserve this cohesiveness. Thus clamshell dredging with scow disposal should generally be used for such operations.

- Point dumping of the material to be covered should be done as accurately as possible, preferably with a taut wire moored buoy as a disposal marker.

- Disposal of the capping material should be accomplished as soon as possible, also using the buoy as a marker.

- After disposal of approximately 2/3 of the capping material at the disposal point, the remainder should be

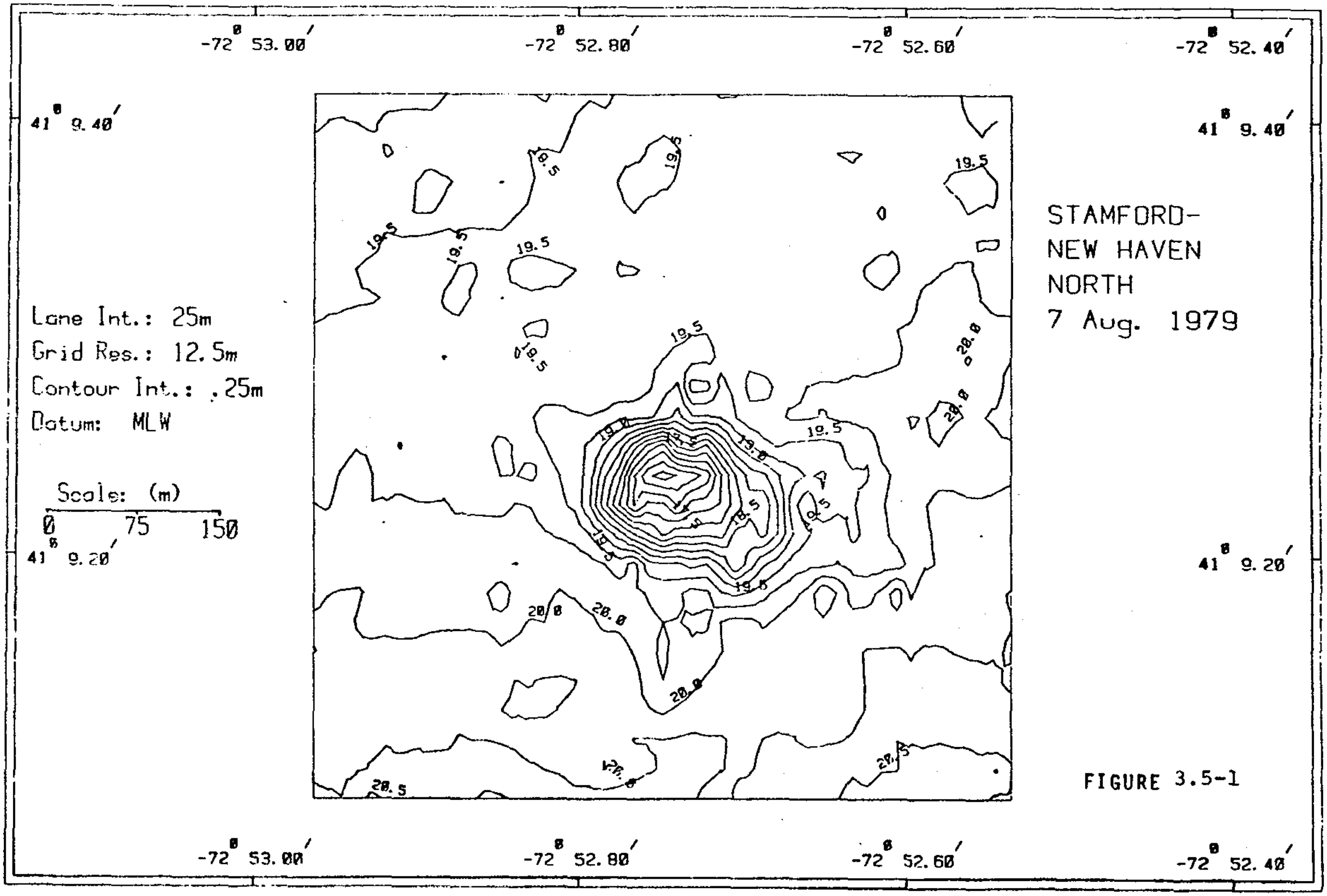

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
STAMFORD-
NEW HAVEN
NORTH
7 Aug. 1979
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: (m)
0 75 150
19.5
20.0
20.5

FIGURE 3.5-1

dumped in a circle with a radius equal to that of the initial spoil mound to insure capping of the flanks.

- Monitoring of the capping operation with bathymetric techniques should be done during disposal to allow for modifications in disposal operations required to insure coverage.

3.5 Post-Disposal Monitoring

Although the operational techniques for capping Stamford sediment with silt and sand from New Haven harbor were successful, the effectiveness of the procedure depends on the stability of the resulting cap and its success in isolating the contaminated material from the biota and the water column. Therefore, following deposition of the capping material the thrust of the monitoring effort changed to evaluation of the stability of the resulting mounds with time. Again, this was a multidisciplinary effort involving physical, chemical and biological measurements. However, the emphasis in this paper is placed on the results of the bathymetric monitoring and their implications toward understanding physical processes acting on the disposal mounds.

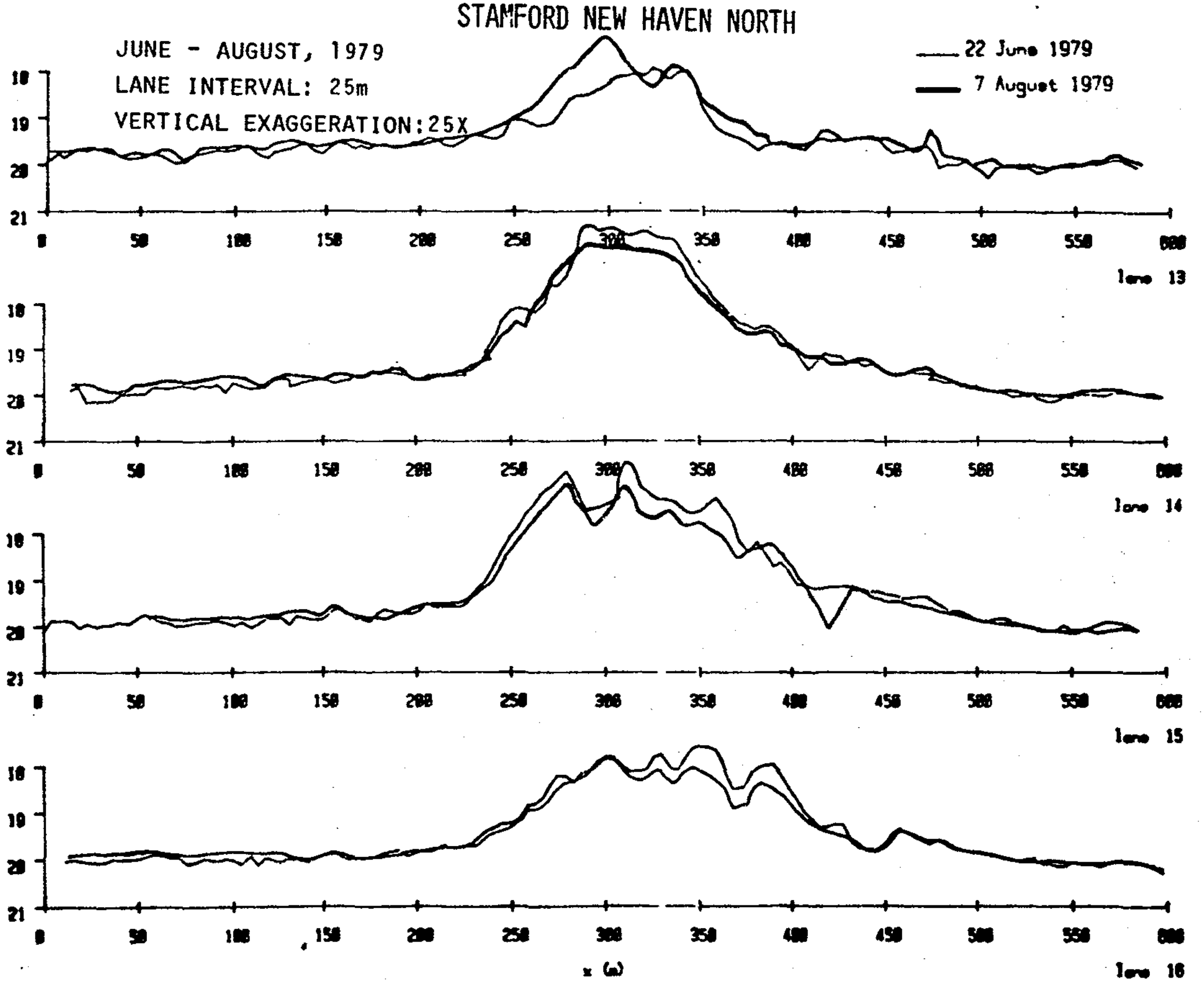
Evaluation of long term changes in the shape and volume of the disposal mounds required an initial baseline for comparison similar to that used in the operational monitoring phase of the project. For post-disposal studies, the June 20 survey of the southern site (Figure 3.4-6) and the June 22 survey of the northern site (Figure 3.4-8) were used.

On 7 August 1979, a bathymetric survey of the north disposal site was conducted (Figure 3.5-1) that indicated there were no significant changes in the topography of the mound. Examination of the depth sections (Figure 3.5-2) supports this conclusion. In all cases except Lane 13, the small scale topographic features were unchanged although the mound had settled or compressed slighly, increasing the water depth by approximately 20 cm. Calculation of volume differences between the June 22 and August 7 surveys indicated that only Lane 13 had an increase in volume while other lanes over the mound showed a slight decrease. Total loss for the entire survey area was approximately 1700 m^3 which was less than the 2400 m^3 resolution of the survey procedure.

No explanation is readily available for the increase in volume for Lane 13. Examination of the survey track shows no deviation from the specified lane at this location eliminating the possibility of navigation error. However, the location of the increase in material is immedately west of the disposal buoy and it is possible that a permit contractor who should have been dumping west of the "SP" buoy could have mistakenly dumped at the North disposal buoy.

A survey of the southern site was also run on August 7, 1979, which, similarly, indicated no major differences in topography of the disposal mound (Figure 3.5-3). Calculation of the volume difference indicated the total volume change for the entire survey was a decrease of 900 m^3 which is well within the precision of the analysis. There was some indication of slumping on the north margin of the mound where a broad decrease in depth from 20-40 cm occurred.

In summary, the results of the August surveys indicated no significant changes in the disposal mounds or the capping material. Slight settling or consolidation of both mounds did



STAMFORD NEW HAVEN NORTH
JUNE - AUGUST, 1979
LANE INTERVAL: 25m
VERTICAL EXAGGERATION:25X
22 June 1979
7 August 1979
18
19
20
21
0
50
100
150
200
250
300
350
400
450
500
550
600
lane 13
lane 14
lane 15
lane 16
x (m)

FIGURE 3.5-2

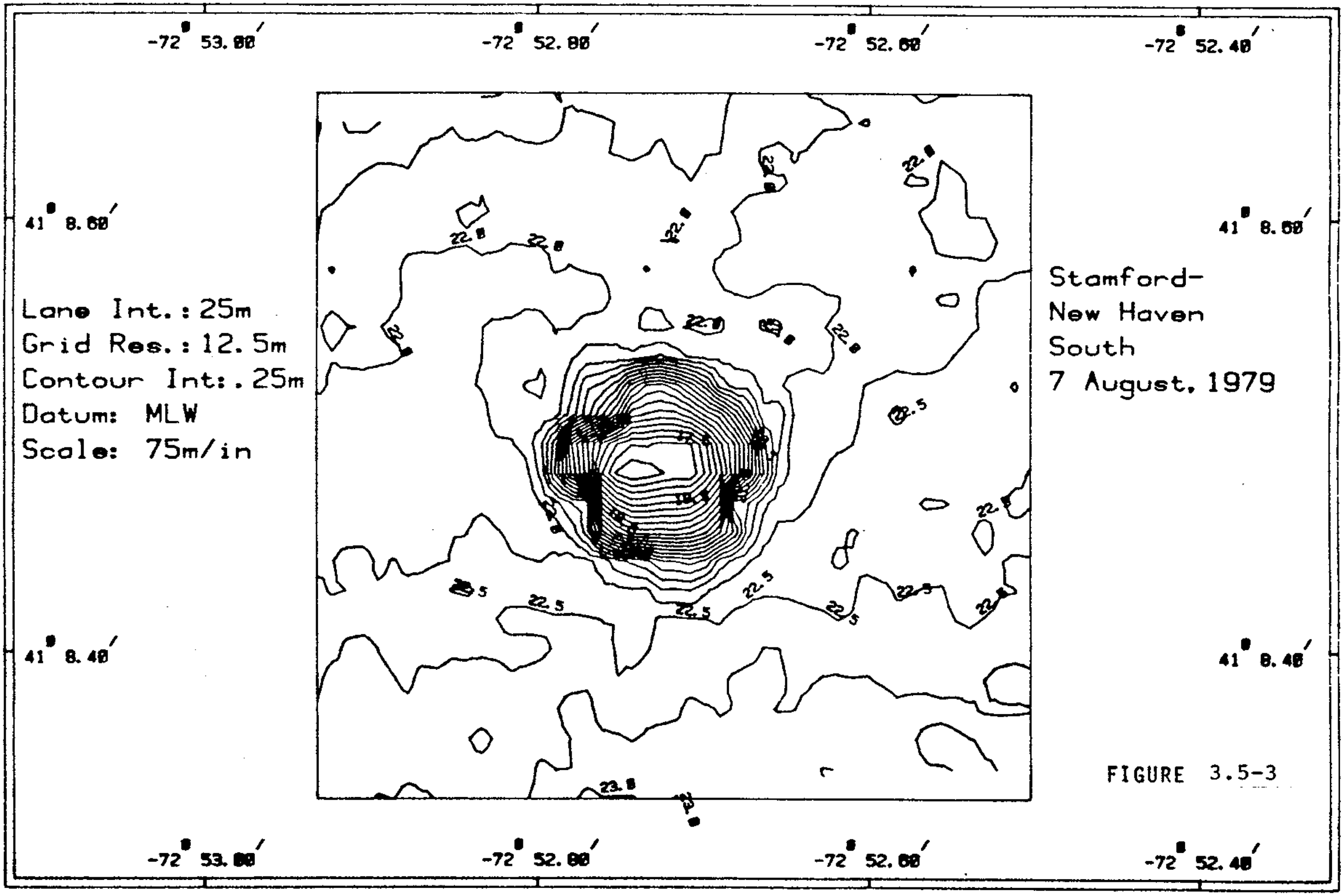

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int:.25m
Datum: MLW
Scale: 75m/in
Stamford-
New Haven
South
7 August, 1979
22.8
22.5
23.0

FIGURE 3.5-3

occur resulting in a 20-40 cm increase in depth on the tops of the piles. These results were expected since the mound from the 1974 dredging operating has been stable for several years indicating the containment potential of the disposal site.

Following the August surveys an additional 6000 m^3 of material from Stamford harbor was deposited at the southern site and a survey was conducted on November 7, 1979, to evaluate changes resulting from the addition of these sediments (Figure 3.5-4). The results of this survey showed a major change in the topography of the mound resulting from the loss of approximately 10,000 m^3 of material from the top of the mound. Depth sections across the center of the mound (Figure 3.5-5) revealed a flat surface at 19 meters indicating that approximately 2 meters of sediment had been removed. Some of that material was present, particularly on the northeast margin of the mound, where slumping had occurred, however, the build-up of material in that area cannot account for all the missing sediment. Although this loss did not expose any Stamford material, further investigations were initiated to determine the causes of sediment movements and to evaluate conditions at the other sites.

The flat topography of the sediment surface at a constant depth suggested that wave action was most likely responsible for the movement of material. The passage of Hurricane David through the area on September 6 provided a possible energy source to create the wave motion required. Consequently, additional work was conducted to survey the other disposal sites and to determine the potential stress exerted on the mounds as a result of the hurricane. Surveys were made of the north disposal site and the

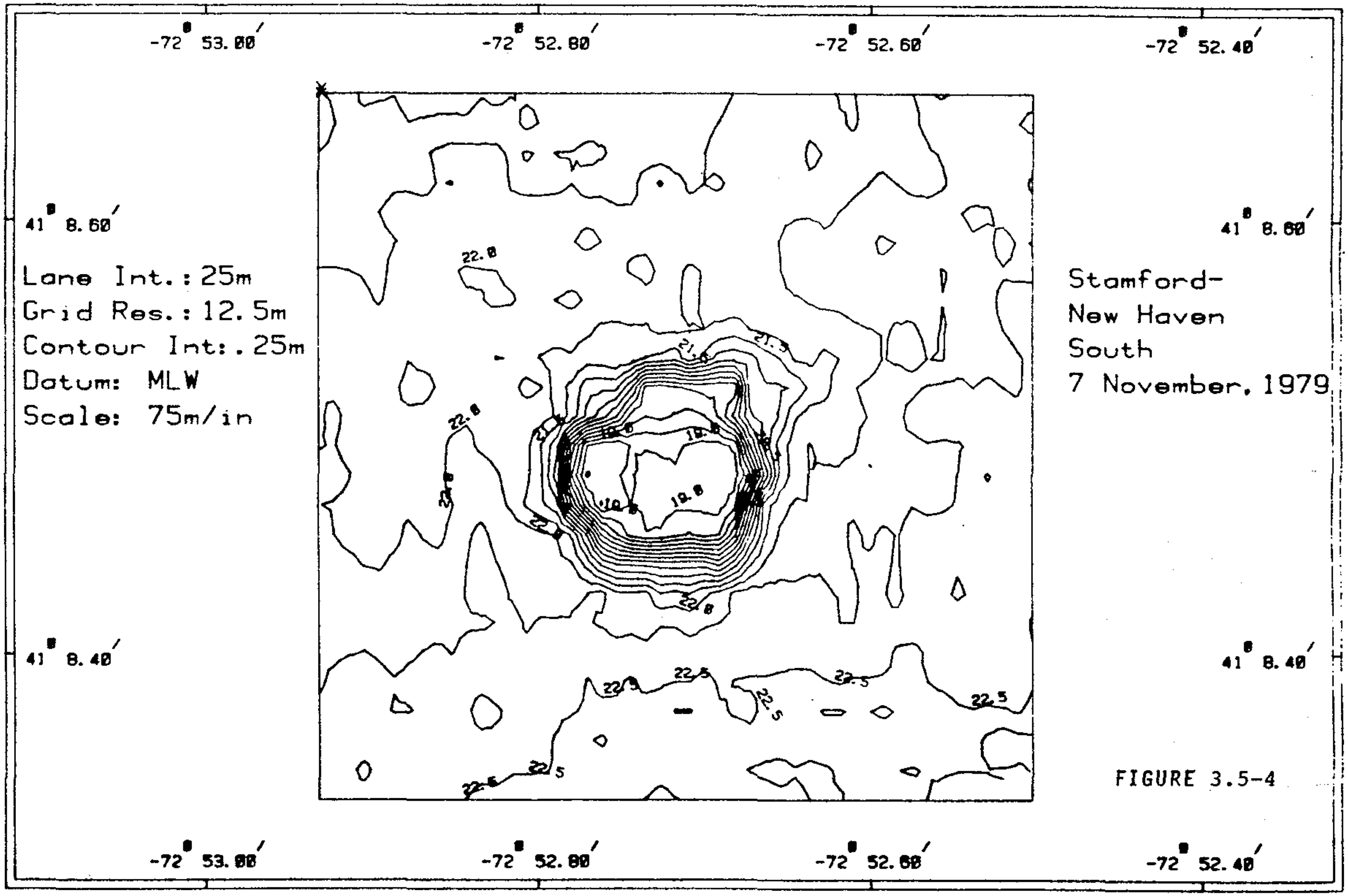

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int: .25m
Datum: MLW
Scale: 75m/in
Stamford-
New Haven
South
7 November, 1979
22.0
22.8
21.5
19.8
22.5

FIGURE 3.5-4

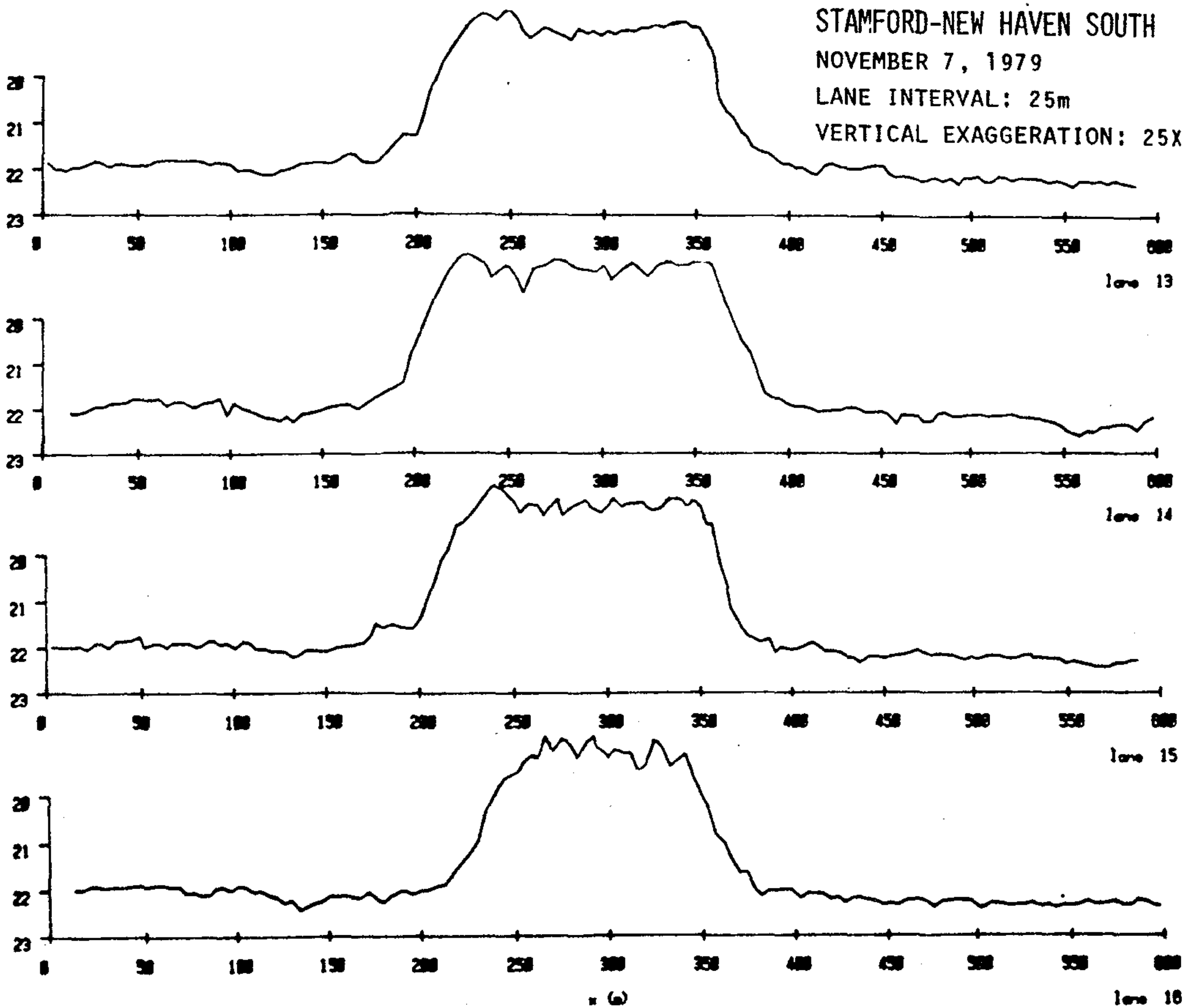


FIGURE 3.5-5

DEPTH PROFILES STNH SOUTH, LANES 13-16
NOVEMBER 1979

1974 New Haven mound on November 15, 1979. Both of these surveys were conducted using the same precision techniques, replicating previous 25 m lanes. Both surveys indicated that no significant changes had occurred in either mound during the period in which the southern site was affected.

It is important to note that both the Stamford-New Haven North and the 1974 New Haven deposit have minimum water depths that are less than the southern site, and thus should have been more susceptible to wave motion. Since these three mounds are all within a mile of each other, on comparatively flat bottom, it is highly unlikely that one site would experience markedly different environmental stress exerted by currents or wave action than would be expected at the other sites. Therefore, an explanation for the loss of material from the southern mound must account for the lack of movement at shallower depths through differences in the physical and lithological properties of the sediments composing the mounds.

The Stamford-New Haven North and the 1974 New Haven mounds are characterized by a surface of fine sand material which is probably thicker on the newer mound. This lithology is in sharp contrast to the cohesive silt surface of the southern mound which is characterized by clumps of cohesive clay interspersed within a fine silty matrix. Furthermore, the slopes of the sand covered mounds are more gentle than those of the southern site, although all three sites exhibit angles less than 5 degrees and should be within a stable angle of repose for the sediment.

There are several reasons to suggest that normal tidal currents are not responsible for the movement of disposed material in this case. First, there has never been any previous indication of significant movement in this area, either on earlier disposal mounds or during this disposal operation. Second, although the motion of the tidal currents is in an east-west direction, the only observed shift of material is in a north - south direction. Finally, a subsequent survey of the disposal site conducted on December 19, 1979 indicated that no further changes in the topography had occurred during the month following the original detection of sediment loss.

Since tidal currents are not likely to initiate sediment motion, the most logical explanation would be the stress exerted on the spoils by wave action or a combination of waves and currents. Because Long Island Sound is a relatively protected area, the generation of long period waves that are capable of affecting sediment at depths greater than 18 meters must be a rare occurrence. However, the passage of Hurricane David may have been just such an event and may have provided sufficient stress to initiate sediment motion.

To examine this possibility, calculations were made of theoretical shear stress developed by hurricane waves over the rough surface of the south site and compared with stress developed over a smooth surface. These theoretical stresses were then compared with estimates of critical shear stress to determine the potential for sediment motion. For unconsolidated fine sand similar to that present on the north mound and the 1974 New Haven mound, the critical threshold would be exceeded in water depths of 14 and 16 m for 4.5 and 5.0 second waves of sufficient height (1.5 m). The wave height in 18 m depth (south pile) must, however, exceed 2 meters with a period of 5 seconds to meet the nominal threshold condition. To estimate stress due to wave motion, it was necessary to hindcast waves based on wind data and fetch distance. The wave hindcast data generated for Hurricane David indicated that development of such long period waves would be unlikely. However, since failure of the top of the 18 m south pile was observed, estimates of the developed shear stress were made and compared.

The spoil mounds differ in depth of water, composition, shape and surface roughness. The south pile is composed of clumps of consolidated clay material surrounded by a fine, silty clay matrix. These clumps protrude into the near bottom flow and will, therefore, develop shear stress due to form drag as well as skin friction. The size of these elements, estimated from bottom photographs and relatively undisturbed grab samples, is approximately 20 cm. The other mounds were covered with fine-medium sand and have a roughness, estimated from the grain size anlysis, of about 0.025 cm.

The Shields Criterion (ψ), which expresses the threshold of sediment motion as a function of sediment properties, was calculated for a grain diameter of D =.025 cm (S^*=3.97) for waves of 4 second period. Shear stresses were then calculated as a function of wave height for both bottom roughness factors (20 cm, .025 cm) (Table 3.5-1).

h = 1800 cm	L_o = 3158.	sinh kh = 18.05	h/L = .5709
T = 4.5	h/L_o = 0.57	k_1 = 0.025 cm	k_2 = 20 cm

H (m)	d_o (cm)	U_m (cm/sec)	$\frac{U_m\, d_o/2}{\nu}$	$\frac{d_o/2}{k_1}$	f_1	$\frac{d_o/2}{}$	f_2	t_1	t_2	ψ_1	ψ_2
1.0	5.54	3.87	$1.07.10^3$	111.	.06	.14	.5	.46	3.85	.011	.09
1.5	8.31	5.80	$2.41.10^3$	166.	.04	.21	.5	.69	8.64	.017	.20
2.0	11.08	7.74	$4.29.10^3$	222.	.035	.28	.49	1.078	15.07	.026	.36
2.5	13.85	9.67	$6.70.10^3$	277.	.024	.35	.49	1.152	23.53	.028	.56
3.0	16.62	11.60	$9.64.10^3$	332.	.020	.42	.49	1.382	33.86	.033	.81
3.5	19.39	13.54	$1.31.10^4$	388.	.016	.48	.49	1.506	46.13	.436	1.11

TABLE 3.5-1. Stress Parameters at 18 meter depths with a wave period of 4.5 seconds and roughness elements of .025 and 20 cm.

The calculated shear stress values for large roughness height are near or exceed the critical value for all tested wave heights (Figure 3.5-6). In contrast, the shear stress developed over a surface of smaller roughness never exceeds the critical value. Consequently, we can conclude that the high roughness factor resulting from the clumps of cohesive sediment on the south site create a greater stress and may cause sediment motion under storm wave conditions, while the smoother surfaces of the other mounds produce significantly smaller stress values, thus insuring the stability of the dredged material even at shallower depths.

MODIFIED SHIELDS DIAGRAM (MADSEN & GRANT, 1970)
WAVE PERIOD T = 4.5 SEC.

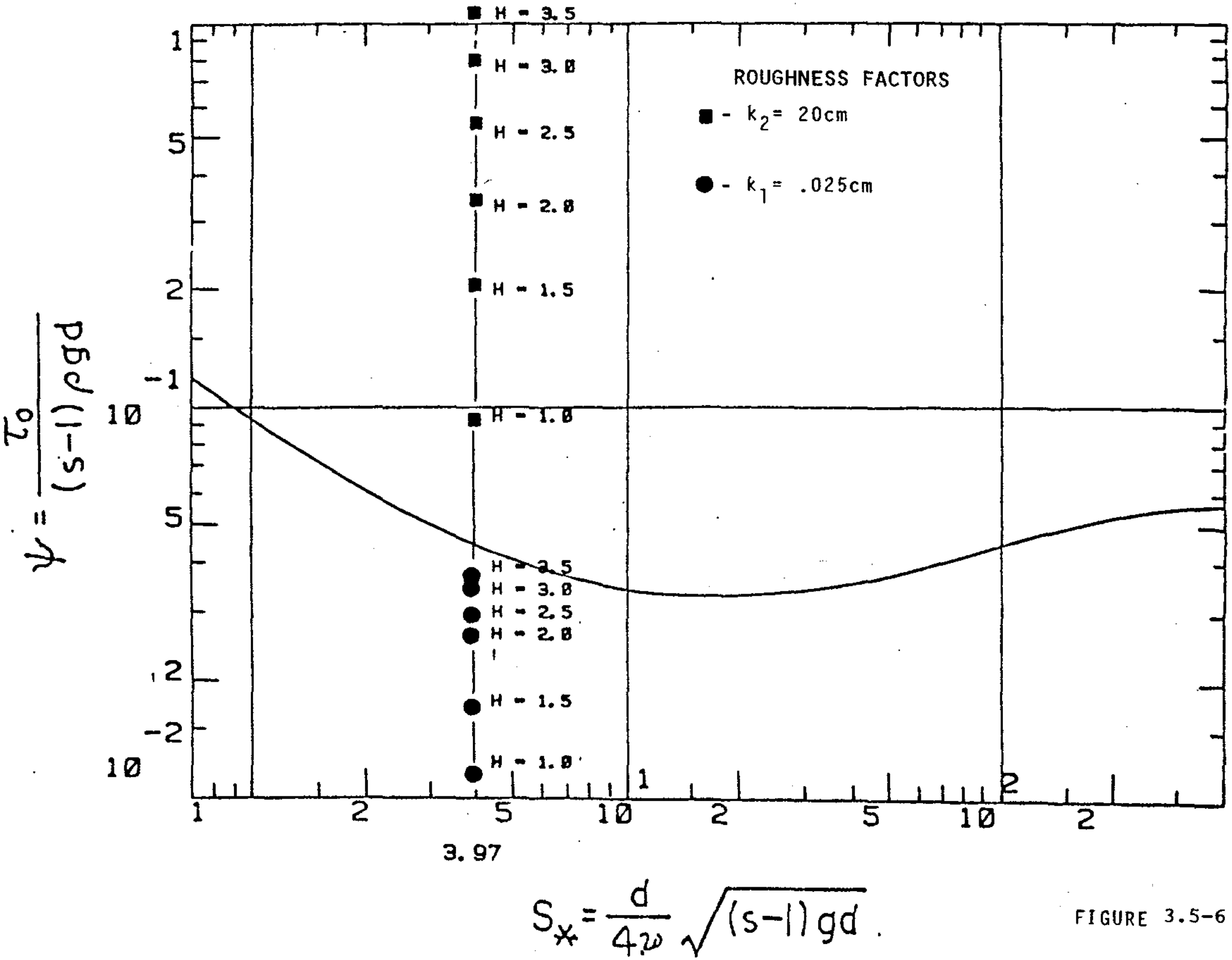


FIGURE 3.5-6

Though the calculations show that this difference could have been the cause of the preferential erosion of the south pile, some factors affecting the accuracy of the results must also be considered. The calculation of shear stress due to waves over the relatively smooth surfaces may be done with some confidence since the relative roughness values are within the range of experimental observation. However, the determination of the stress over a surface of very great relative roughness must be considered more of an estimate. Without field observations under these conditions, it is unknown how the stress is partitioned between skin friction, which may cause erosive failure of the block, and form drag, which may physically move the block or cause eddies which entrain interstitial material. Furthermore, actual Shields criteria for consolidated sediments are essentially unknown and can only be estimated as substantially greater than unconsolidated sediments.

Further investigation should be pursued in order to determine:

- the mode of failure of the blocky material under conditions of high shear stress.
- the degree of consolidation and cohesion of the bottom sediments (dredge pile, sand cover, block) and the effect of these parameters on erodability of dredged material.
- the partitioning of shear stress over beds of large roughness under waves and currents.

3.6 SUMMARY

The precision bathymetric survey procedures employed to monitor the Stamford-New Haven disposal operation have been successful in managing the capping operation and in monitoring changes that have occurred after disposal. With proper control of the disposal operation, these procedures can readily be applied at other locations.

The capping of relatively contaminated dredged material with cleaner sediments appears to be an effective management procedure. There is some question as to the long term stability of the silt cap since the loss of silty clay material from the New Haven south site amounted to 10,000 m^3 or approximately 12% of the total capping material. However, since all of this material was lost from the upper surface of the mound no exposure of Stamford sediment occurred. Furthermore, there is substantial evidence to suggest that the changes observed at this site resulted from stress exerted by the storm prior to stabilization of the mound and that once equilibrium with the environment has been attained no further changes would be expected.

Observations of the sand capped mounds in the Central Long Island Sound Site have indicated successful capping since they have shown no measureable changes in volume or distribution, even though these deposits have more shallow minimum water depths than the southern site. An explanation for the selective movement of sediment on the south site has been proposed based on the interaction of storm waves resulting from Hurricane David and the roughness parameters of the cohesive New Haven material.

The implications of these conclusions are important to future disposal and/or capping operations. Consolidated, cohesive sediments are common in the New England area, and clamshell dredges which preserve the cohesive nature of the material must be used to reduce suspended load and spreading of material at both the dredging and disposal sites. Consequently, while these properties aid in reducing the area of coverage, most mounds will have surface roughness comparable to the New Haven south site after disposal. These features have been observed at the New London site, but the cohesive clumps have broken down over a period of time primarily due to biological activity, but also as a result of fracturing and erosion.

From the results of this study, it is apparent that the stress created by the roughness factor associated with these clumps under storm wave conditions is more important than the depth of the mound surface, the strength of currents, or the cohesive nature of the sediment in determining the stability of disposed material. The occurrence of a major storm such as Hurricane David before the surface of the mound has been smoothed by other natural forces thus creates a potential for large scale erosion and transport of material.

Future disposal operations might, therefore, consider methods to produce a smooth surface at the conclusion of the dumping procedure. Such methods could include:

- capping with sand material, as was done at the north New Haven sites
- dredging and disposal of less cohesive sediments near the end of the operation
- disposal of cleaner material from the mouth of the estuary after artificially increasing the water content of these sediments to break down cohesion
- artificially smoothing the surface through dragging

Additional work is needed to determine if these procedures are in fact necessary and to more accurately evaluate and predict the reoccurrence of the effects observed at the New Haven south site. The problem of stability is being addressed to some extent under the DAMOS program through a combination of bottom turbulence and erosion studies. However, the phenomena observed at the Central Long Island Sound Site emphasize the importance of monitoring disposal areas and of understanding the interaction of the energy regime with dredged material.

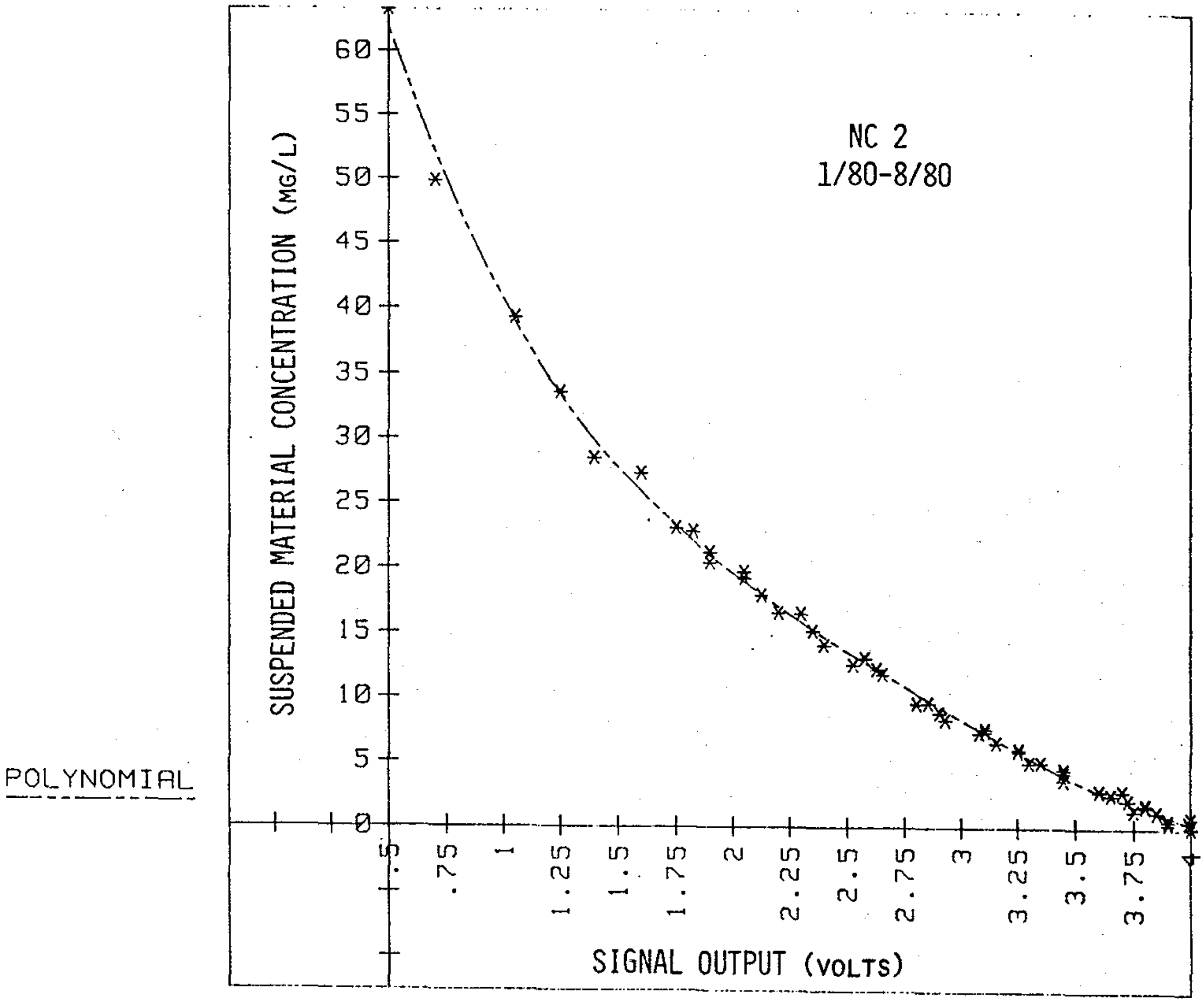


FIGURE 4.2-3. Nephelometer No.2 Calibration Curve

4.0 Suspended Sediment Transport Program

4.1 Introduction

Evaluation of the impacts induced by the disposal of dredge material in coastal waters requires an understanding of the variety of factors affecting sediment transport and the ultimate mobility of associated organic and inorganic contaminants. Of these factors aperiodic storms represent perhaps the most difficult to define quantitatively. The occurrence of these high energy, short term events is difficult to predict and their intensity often precludes direct physical sampling. As a result, hard data detailing storm induced resuspension is limited and estimates of associated impacts are often based on simple qualitative observation.

In the late spring of 1979, an investigation designed to directly monitor storm induced resuspension within selected New England coastal areas was initiated. As part of this study, an instrumentation array intended to provide reasonably long term, in situ observations of suspended sediment was designed and constructed. This unit, first deployed during January, 1980, has during the past year, provided data under a variety of climatic and seasonal conditions. These observations clearly document the response of a typical coastal system to aperiodic storm events and permit quantitative evaluation of the effects of these events on deposits of disposed dredged material.

The following report details the components of the primary instrumentation array and presents the results of the field observations obtained using this array during the period

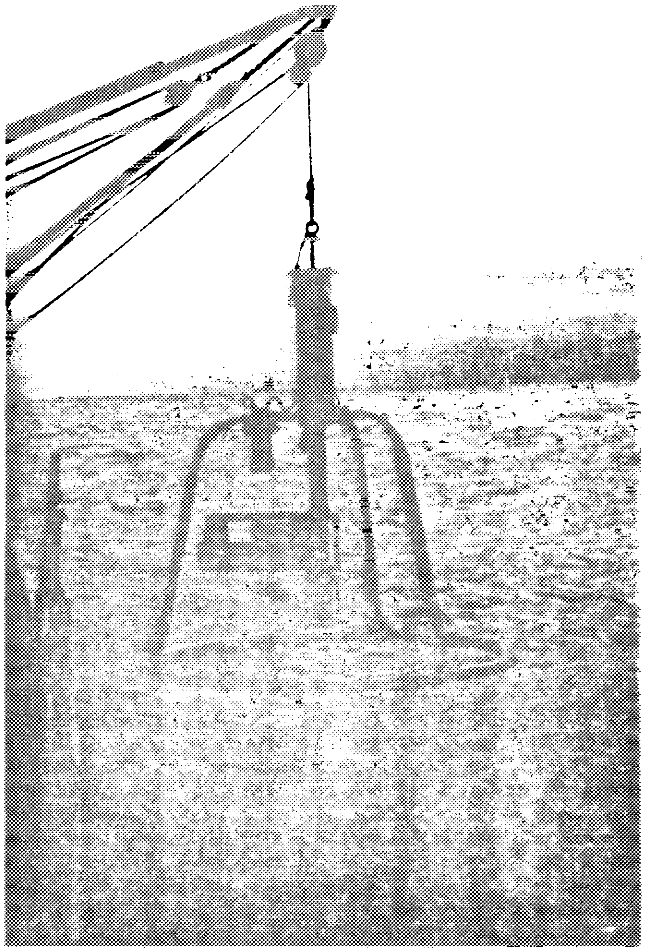
January to June 1980.

4.2 Instrumentation Array

During the initial phases of this investigation, emphasis was placed on the design, construction and testing of an instrumentation array sufficient to provide long term in situ observations of near bottom suspended material conditions in selected coastal areas. The array was to be self contained with integral power and data recording and was to be capable of either stand alone operation or supplementary operation as part of a large system built around the Naval Underwater Systems Center's (NUSC) high resolution boundary layer turbulence current meter system (BOLT). The completed array is shown in Fig 4.2-1.

The package consists of a control network and four basic subsystems mounted in an aluminum frame. These four subsystems are: 1) an optical array, 2) a current meter system, 3) a camera and 4) a pump filtration unit. The frame outline is designed to minimize flow disturbance while providing reasonable stability and ease of handling. The circular base is approximately 2.0 m in diameter and is semi circular in cross section. The base is half filled with lead. The remaining area is filled with concrete to prevent lead contamination of local water or sediment samples and to provide a rugged footing and additional ballast for the array.

The frame is approximately 3 meters in height. Three aluminum pipes (6 cm in dia.) forming the outer legs are bolted to the periphery of the base and extend upwards to be joined by a circular horizontal aluminum plate. This plate provides a central strength member and serves to support a section of heavy walled



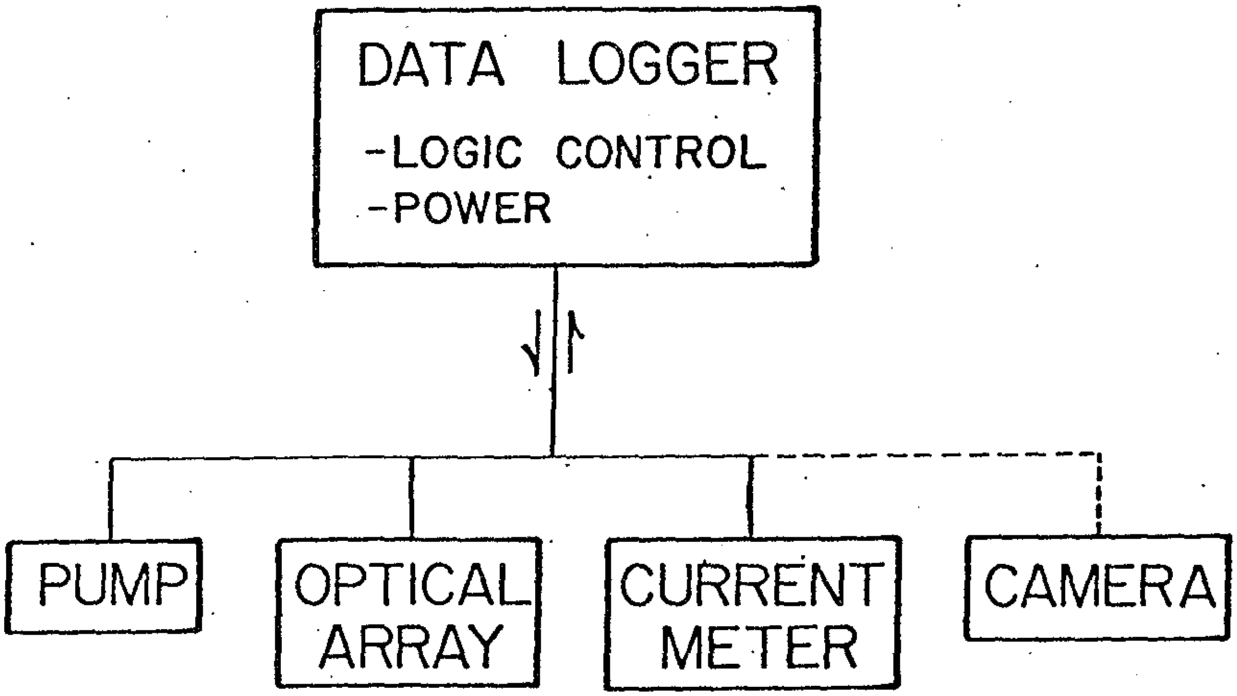
Bottom Mounted Instrumentation Array
Deployment No.1 Configuration

FIGURE 4.2-1

aluminum pipe (~10 cm in dia.) extending downwards approximately 1.5 m and a support tie rod configuration extending upwards 1.0 m. At their upper limit, the tie rods are joined by a second horizontal aluminum plate. A stainless bail is bolted to the upper side to this plate to provide a secure lifting point for the array.

The systems' configuration is shown schematically in Figure 4.2-2. The primary control of the array is provided by a digital data logger (Sea Data Model 651-8). This unit, located near the top of the array (Fig. 4.2-1), also supplies power to selected instruments and serves to record the output signals from the current meter, optical array and the temperature and salinity sensors. These data are stored on magnetic tape cassettes with capacity sufficient to permit sampling of all instruments four times an hour for 36 days. The format of the stored data is system specific and requires conversion before analysis. Conversion is accomplished using a Sea Data Model 12A reader in combination with a Digi Data magnetic tape drive. The resultant nine track tape contains data in an IBM compatible format and is easily read using standard programming procedures.

The optical array is designed to provide indirect samples of suspended material concentrations at a fixed position above the sediment water interface. The array consists of two red light transmissometers. Designed to be relatively insensitive to dissolved materials (particularly color-rich organics) and water matrix variations, each of these units provides an analog output proportional to the concentration of sediments suspended over a fixed path length of 10 cm. Path length was specified following



Instrumentation Array
Primary Subsystems

FIGURE 4.2-2

an evaluation of instrument sensitivity and examination of ambient suspended material concentrations and the characteristic variation expected at the selected study area. Output characteristics were defined following individual laboratory calibration of each instrument over a range of suspended material concentrations prepared using natural sediments found in the vicinitiy of the deployment site. Plots of these calibration data (Fig. 4.2-3) show the optical sensors to be reasonably sensitive with output voltage increasing progressively as a function of concentration. The output was only slightly non linear and analyses indicate that it can be described adequately for a fourth order polynomial. Such an algorithm is developed for each nephelometer and subsequently used to convert voltage outputs to equivalent suspended material concentrations in milligrams per liter (mg/l).

The current meter system consists of a single savonius rotor and attendant compass and vane mounted at the lower end of the section of heavy walled aluminum piping (Fig. 4.2-1). This device, located approximately 0.5 m above the sediment water interface, serves to monitor mean flow conditions prevailing near bottom and provides a measure of their temporal variability. The system is a simple oceanographic analogue of meteorological instrumentation routinely used in climatic studies. As such, it is viewed primarily as an event monitor and is not expected to provide detailed data on near bottom velocity structures or associated shear stress distributions. Those latter data were to be provided by the NUSC supported BOLT system.

Two forms of signal output are provided by the current meter system. Flow speed induces rotor rotation which, via

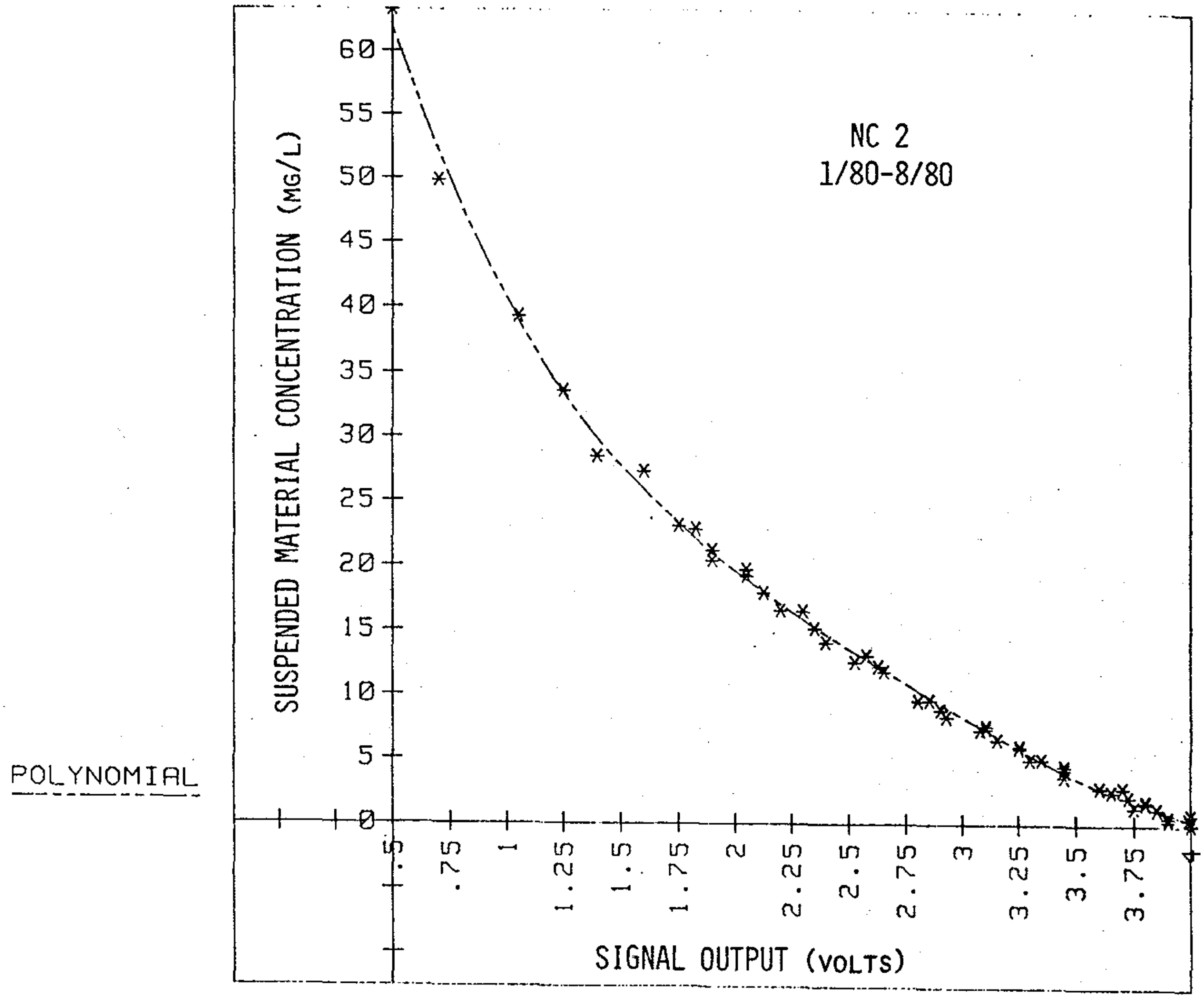


FIGURE 4.2-3. Nephelometer No.2 Calibration Curve

closure of a magnetically activated reed relay, produces a proportional analog voltage output. Output characteristics were determined by laboratory calibration prior to system deployment. The resultant calibration curve is shown in Figure 4.2-4. System response appears to be slightly non-linear and again can be adequately described using a fourth order polynomial. The expression developed by this calibration procedure has been used as the conversion algorithm for all 1980 deployments.

Flow direction affects alignment of the compass reference vane. This orientation is recorded photographically by the lapsed time camera system. The camera system, mounted near the top of the legs in the vicinity of the control strength member (Fig. 4.2-1), consists of a modified super 8mm movie camera and a strobe lighting unit (Vivatar). Both components are mounted separately in watertight PVC housings. The front windows for each unit are clear plexiglass with no optical correction. Shutter speed and lens aperture are adjusted to provide a sufficient depth of field to permit simultaneous viewing of the current meter vane and the more distant sediment water interface. As in the case of the current meter, this unit is intended to serve primarily as an event monitor. Detailed process information requires a larger format and improved optics.

Electronically, the camera system is controlled by a circuit contained within the camera housing. This network receives command information from the Data-Logger and in turn activates the camera and associated strobe light. As presently designed, a single frame of film is exposed during each array sampling sequence. A standard film cassette contains

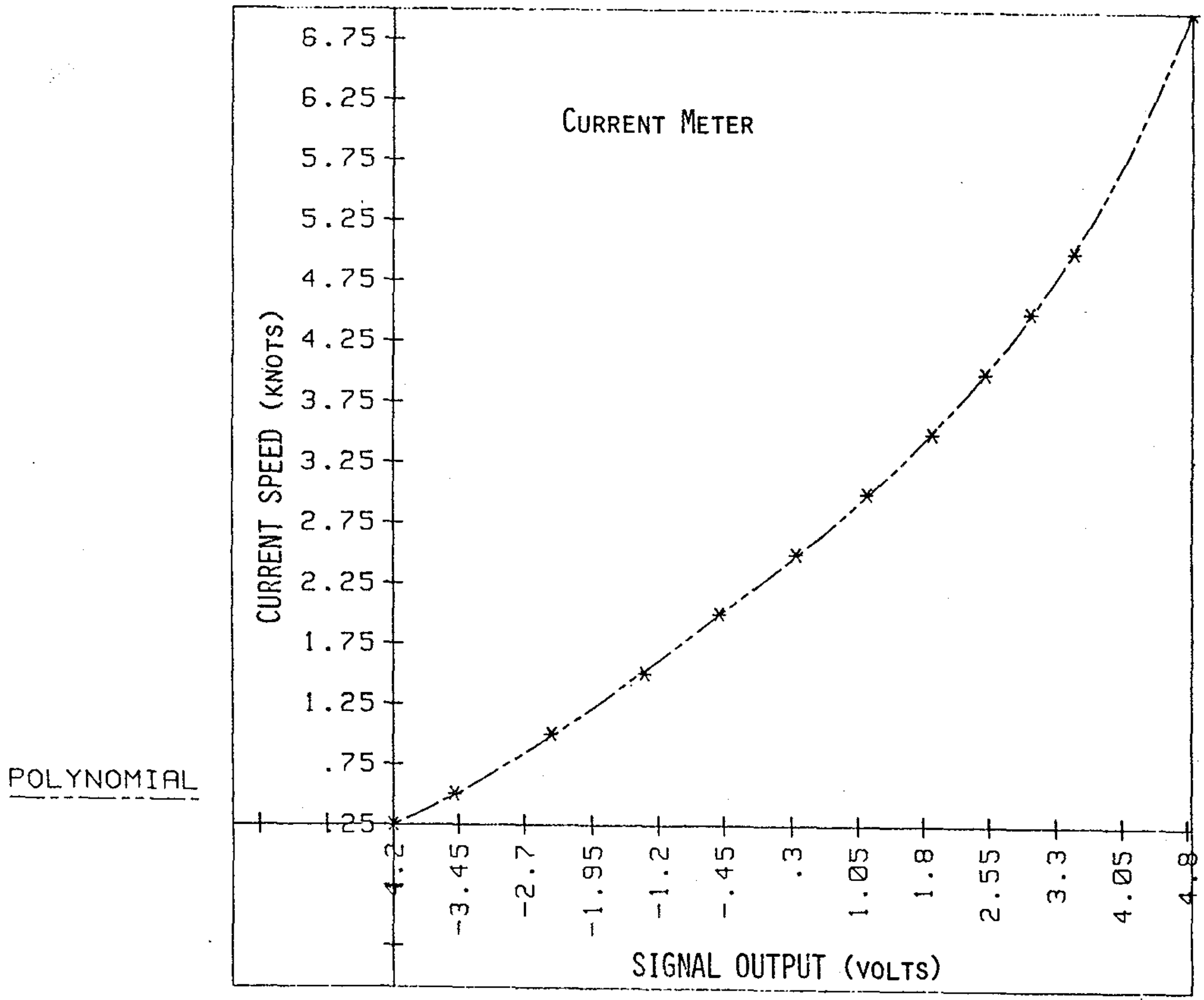


FIGURE 4.2-4. Savonius Rotor Current Meter Calibration

approximately 3000 frames, allowing a deployment duration in excess of one month at a sampling rate of four exposures per hour.

The final subsystem within the primary array consists of a pump filtration unit. This unit is nearly neutrally buoyant in seawater and is attached to a freely rotating sleeve located just above the current meter. It is designed to supplement the optical system by providing direct samples of suspended material concentrations. It simultaneously permits instrument calibration and determination of the composition of the suspended load. The initial design consisted of a variable volume positive displacement pump and a series of 36 in line filtration units, each containing a 47 mm 0.4μ Nuclepore filter. The filtration units were attached to a central manifold containing a sliding piston which, in turn, was attached to the intake line of the pump. As the piston was slowly driven along the length of the manifold, filters were sequentially placed into the intake line. Piston position and excursion rate determined the filters being sampled and sampling duration, respectively. In the initial configuration, a relatively low sampling rate was selected providing one filter per day at a pumping volume of 0.7 liters per day. Sampling was controlled and powered internally and no attempt was made to synchronize the filtration sequence with the array sampling rate.

The pump filtration unit was included in the first array deployment performed during January, 1980. The results of this deployment indicated that the unit as designed and constructed was seriously deficient in several ways. In particular, there were questions concerning the accuracy of the timing which controlled the drive and sampling rate of the pump, since on recovery, the piston excursion indicated a 16 day rather than the actual 13 day deployment. Primary concern, however, centered on the accuracy of the suspended material sample. Comparison of the filters sampled during deployment with those presumbly unsampled, indicated that both contained similar masses of sediment. It was unclear whether the samples were the results of diffusion, biological growth, or the planned filtration. Given the sediment weights contained on the expended filters, it was apparent that the filtration provided by the pump assembly was at best inefficient. A review of these results and probable causes suggested that substantial structural and design modifications were required in order for the unit to function properly. This conclusion was communicated to the manufacturer, and the unit was returned for his examination. Some of the suggested modifications were implemented and the unit was redeployed during the fourth sampling interval in June 1980. The unit again failed to function properly, and its service was discontinued. The pump filtration unit will be replaced by a new mechanical sampler scheduled to be completed during the fall of 1980.

Supplementing the primary array systems are two systems designed to provide concurrent measurements of water temperature and conductivity. Temperature is measured at two points along the vertical supports using protected thermistors (Fenwall Electronics Model 15-K4119) housed in PVC pressure cases. One unit is mounted just below the uppermost horizontal plate and lifting bail, the second is attached to a vertical leg just above the annular base

(Fig. 4.2-1). Each unit was individually calibrated against laboratory standards prior to deployment. A representative calibration curve is shown in Fig. 4.2-5.

Conductivity is monitored using a single sensor mounted within the perforated segment of the vertical, heavy walled tubing (Fig. 4.2-1). This sensor consists of a three electrode flow-through cell and associated electronics (Sea-Bird Model 4-01). The system provides a frequency output proportional to conductivity. Conversion is accomplished by a counting network located within the Data Logger where the counts are subsequently converted to equivalent conductivity using an algorithm supplied by the manufacturer.

4.3 Study Area

The initial series of field investigations placed primary emphasis on determining the sediment transport characteristics in the vicinity of the New London Disposal Site. This area is located approximately 2.5 km south of the entrance to the Thames River, near the eastern passes to Long Island Sound (Fig. 4.3-1). Depths in the area range from twelve (12) to twenty-five (25) meters with circulation dominated by the semi-diurnal tide. Near surface tidal currents display peak values of approximately 1.5 knots. The volume of discharge from the Thames River averages less than 56 m^3/sec and exerts minimal influence on the local density structure.

The wind field characteristic of the eastern Sound varies seasonally. Winter months are typically dominated by northwesterly winds and summer months by southwesterly winds.

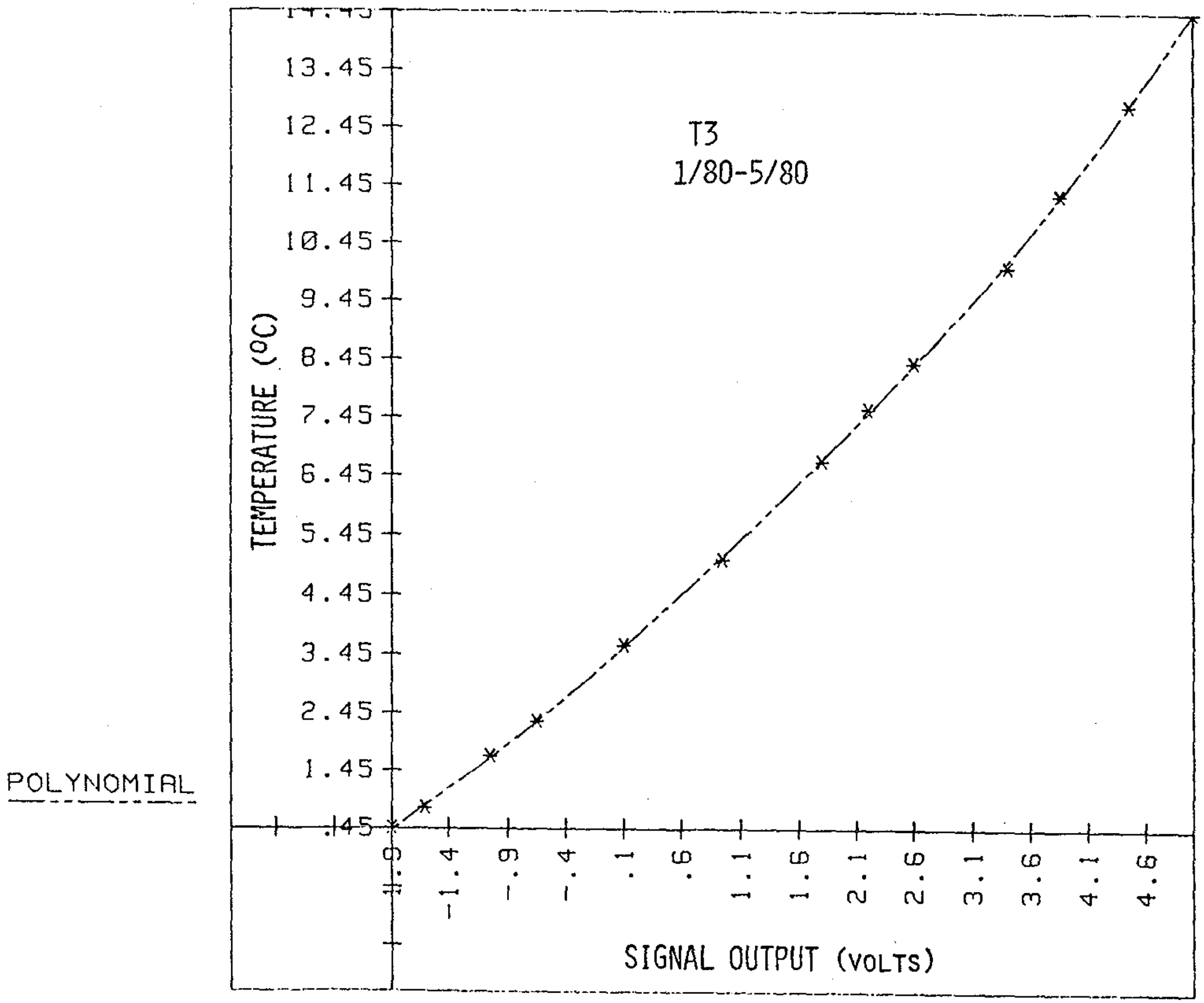


FIGURE 4.2-5. Temperature Probe Calibration Curve

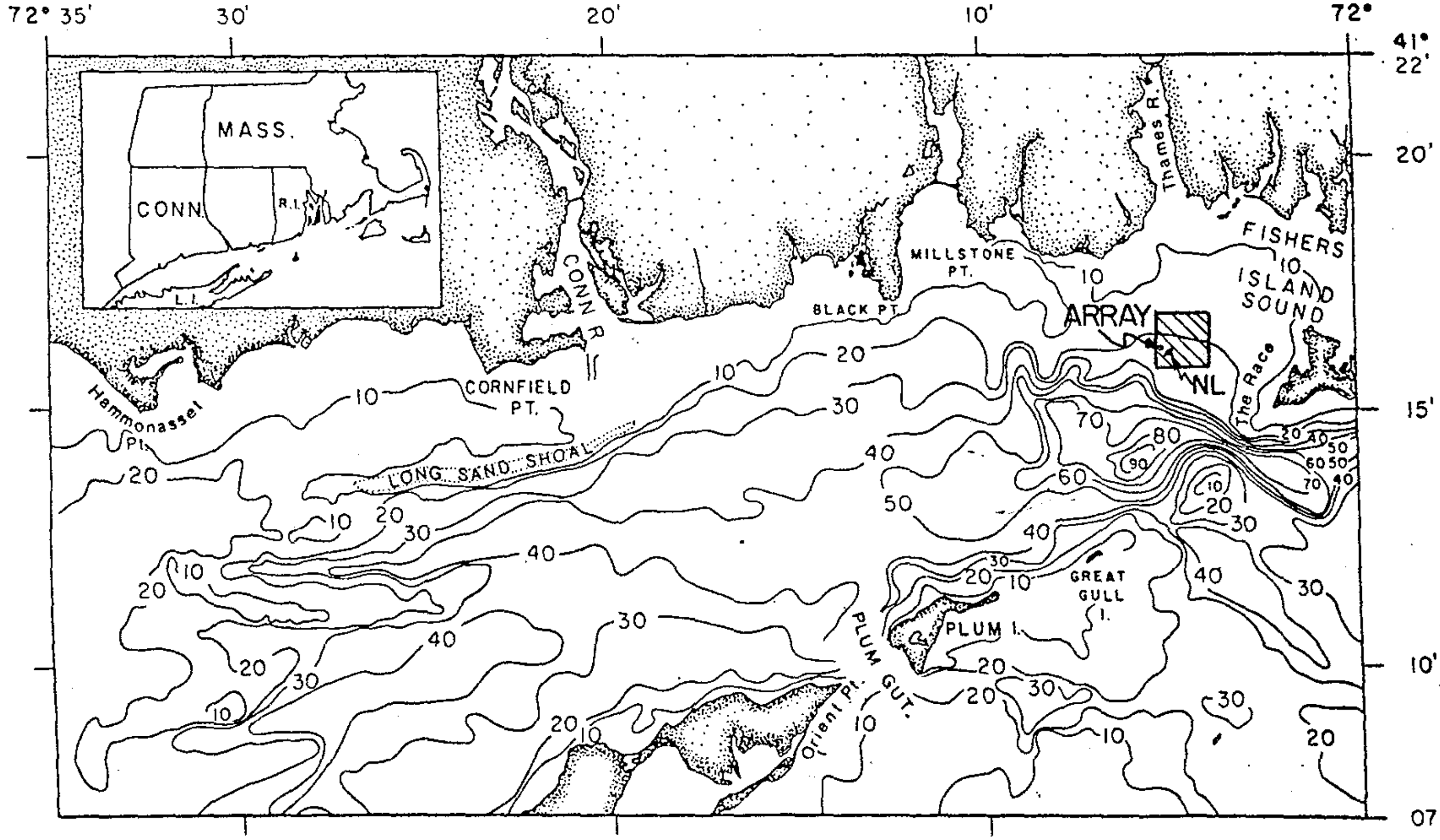


FIGURE 4.3-1. Eastern Long Island Sound

Cross-Hatched Area Represents The New London Spoils Disposal Area

Dot Northwest of NL Buoy Designates the Location of Instrumentation Array During 1980-1981 Monitoring Sequence

Occasional high energy storm events can ocur throughout the year, although maximum frequency of occurrence is generally confined to the late fall, winter, early spring period.

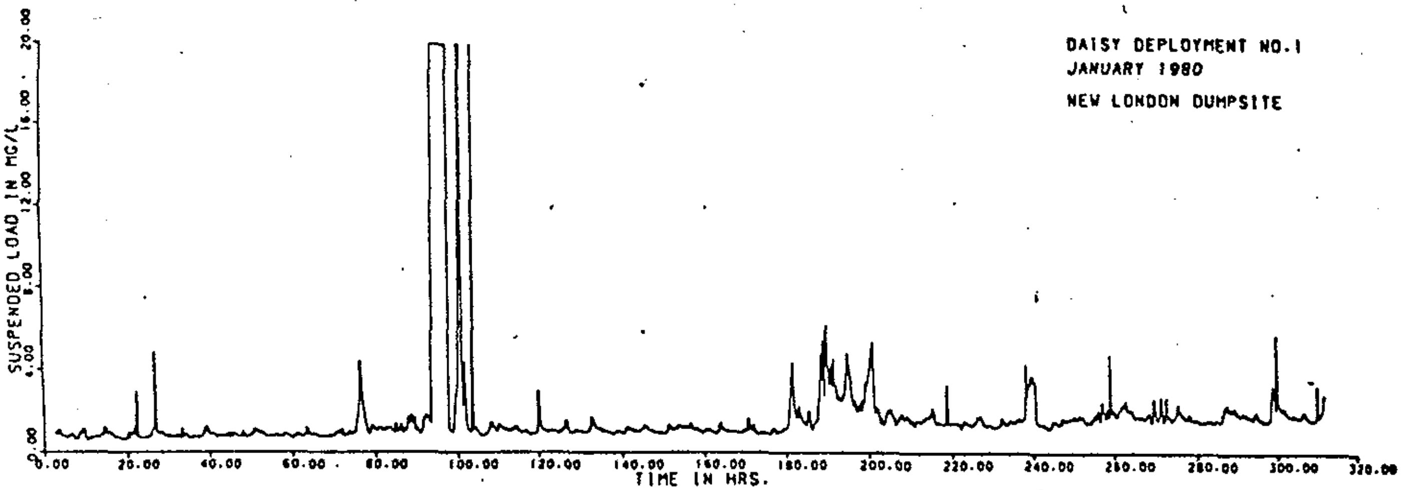
4.4 Results

4.4.1 Deployment No. 1 January 4, 1980 - January 17, 1980

The instrumentation array was deployed on January 4, 1980, with the unit placed at a location along the western limit of the New London Disposal Site in approximately 20 m of water (Fig. 4.3-1). The control unit was programmed to activate and scan all sensors every 15 minutes. The system ran continuously for thirteen days, after which the array was recovered and the data processed. The resultant data are shown in Figures 4.4.1-1 and 4.4.1-2.

Suspended material concentrations (Fig. 4.4.1-1a) during this initial deployment displayed relatively little variability. Eliminating the anomalously high spike near 100 hours as being caused by aberrant fouling or close proximity to disposal of dredge spoils, concentration levels varied between 2.5 and 6.5 mg/l. The progressive increase noted after 180 hours was most probably the result of sediment residue retained on the optical windows following a resuspension event. Fouling may also be suspect although examination immediately following recovery showed no evidence of biological growth or microbial slime.

The nephelometer record (Fig. 4.4.1-1a) indicates that during the deployment period, several events occurred of sufficient magnitude to produce resuspension and increase local



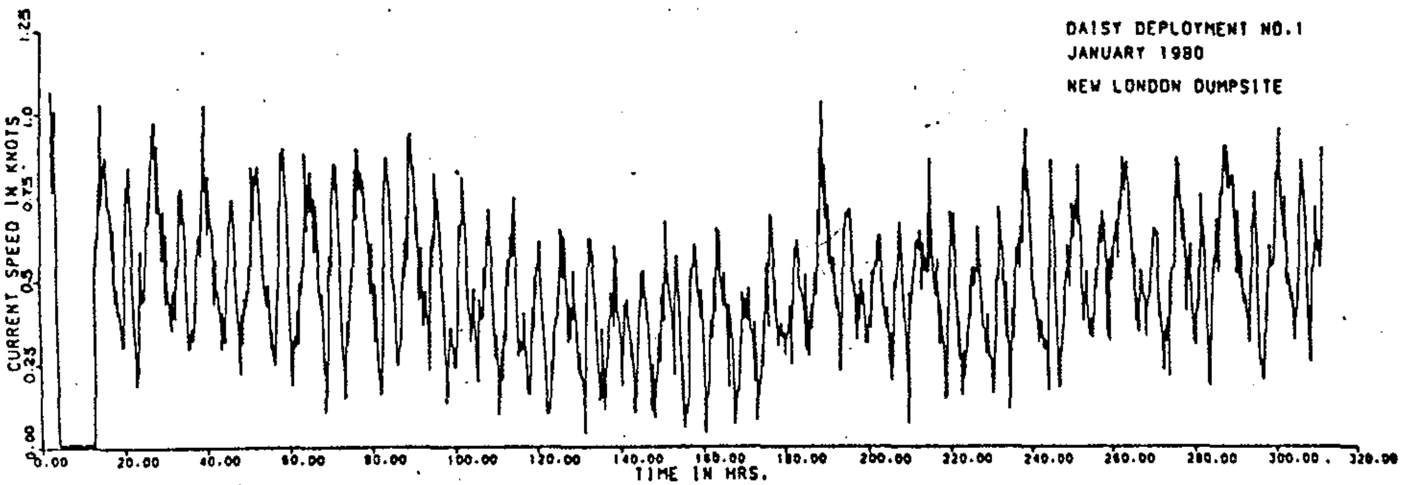
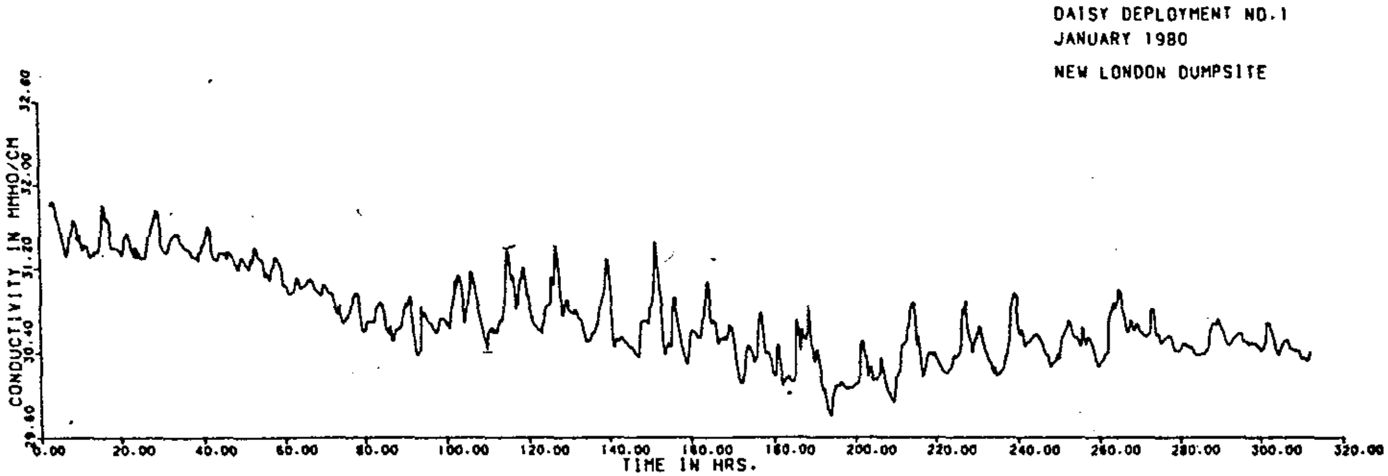


FIGURE 4.4.1-1a (upper) Suspended Material Concentrations

FIGURE 4.4.1-1b (lower) Near-Bottom Current Speed



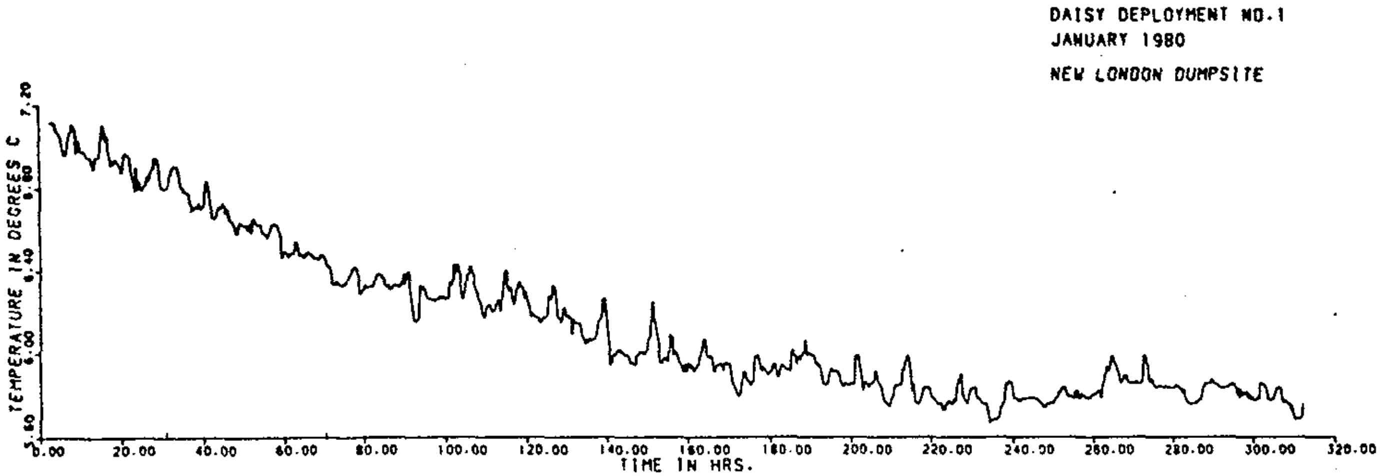


FIGURE 4.4.1-2a (upper) Conductivity At 1.0m Above Bottom

FIGURE 4.4.1-2b (lower) Representative Near-Bottom Water Temperatures suspended material concentrations. Measurable perturbations occurred on Day 2 (~26 hrs) Day 3 (~76 hrs), Day 7 (~198 hrs), Day 10 (~240 hrs), Day 11 (~260 hrs) and Day 12-13 (~ 300 hrs). With the exception of the event which began on Day 7, these perturbations were short-lived and persisted for less than five hours. The Day 7 event persisted for the better part of 24 hours and must be classed as a major transport event.

In Eastern Long Island Sound, increases in suspended material concentrations are induced by the combined effects of winds and tidal currents, and sediment loading introduced by freshwater streamflows.

Examination of the temperature-conductivity data obtained during Deployment 1 (Figs. 4.4.1-2a and 4.4.1-2b) indicates no significant freshwater inputs occurred during the deployment and suggests that the observed perturbations are the result of wind and tide-driven resuspension. Separating the influence of these two factors is difficult. Previous studies have shown that tidal currents in Long Island Sound induce relatively minor amounts of resuspension and serve primarily to distribute sediments suspended by other mechanisms (Bohlen, 1975). Within the study area, examination of the correlation between suspended material concentrations (Fig. 4.4.1-1a) and local current speeds (Fig. 4.4.1-1b) yields similar results. Under typical flow conditions, material concentrations display variations of less than ± 10% over the tidal cycle. Maximum concentrations coincide with periods of maximum current. These characteristics suggest that the sediment-water interface is very nearly in equilibrium with the available average flow energy.

Perturbations in excess of tide induced variations require additional energy inputs.

Resuspension in excess of that attributable to tidal activity can only be produced by the local wind field acting through suface waves and/or wind stress induced currents. A review of wind records (Fig. 4.4.1-3) obtained during Deployment 1 at a shore station just north of the study area shows a clear correlation between periods of high energy winds and the major suspended mateial perturbations (Fig. 4.4.1-1a). This correlation is particularly evident for the Day 3 (~76 hrs) and the Day 7 (~180 hrs) events. Correlations can also be discerned for each of the remaining events and none appear to have occurred in the absence of significant wind velocities.

All resuspension events display some significant similarities and differences. Events induced by relatively low wind velocities (typically less than 30 km/hr) tend to apear as a well defined spike coincident in time with the period of maximum tidal velocity. Wind velocities above 45 km/hr produce relatively minor increases in the magnitude of resuspension but are of significantly longer duration (compare Day 2 to Day 3 to Day 7, Fig. 4.4.1-3. Even during the longest duration events, however, the pattern remains "spiky" with each peak essentially coincident with the tidal velocity maxima. This continuing coincidence suggests that the observed resuspension is not simply the result of wind induced factors but rather due to the combined effects of winds and tidal currents. It appears that either factor acting alone is unable to induce significant resuspension.

The duration of high velocity wind events appears to be

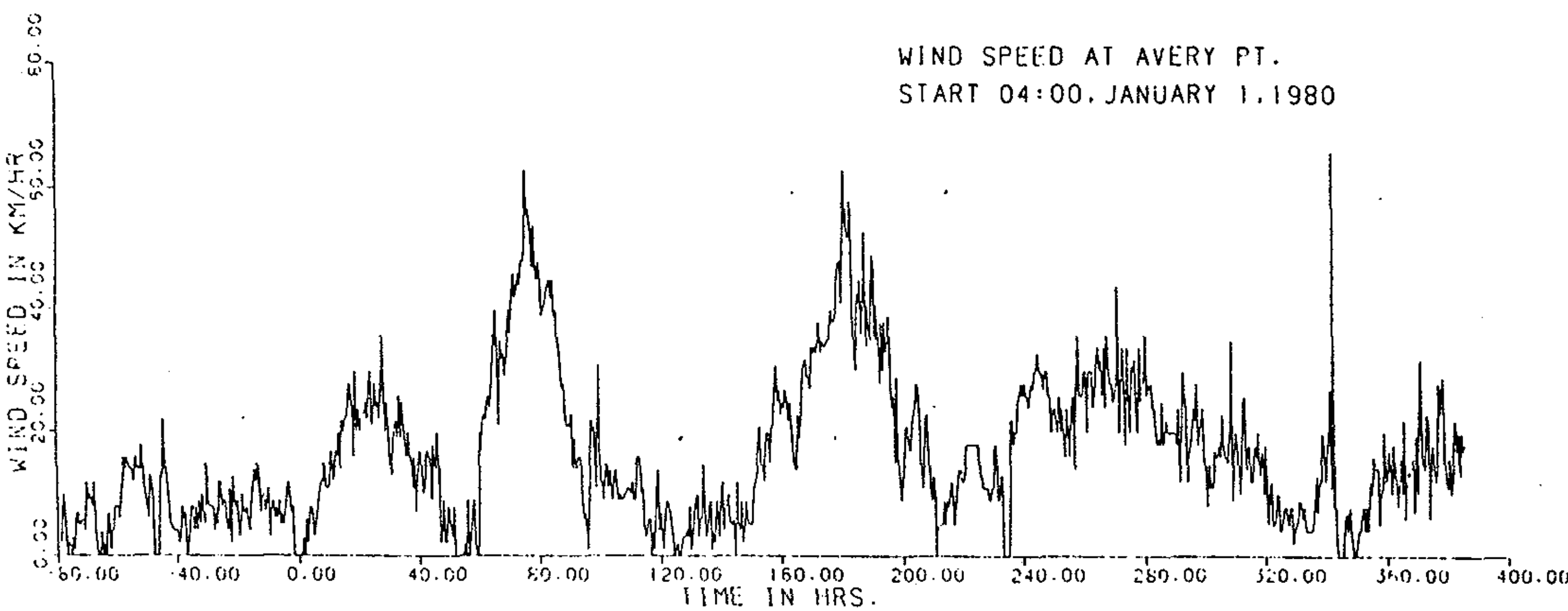


FIGURE 4.4.1-3. Wind Speeds At 10m Elevation-Deployment No.1

a controlling factor affecting resuspension. The high velocity wind episodes which occurred on Day 3 and Day 7 were essentially similar with both events displaying peak velocities of approximately 60 km/hr from a predominantly south to southwest direction. However, above average wind velocities for the Day 3 event lasted for approximately 35 hours compared to 55 hours for the Day 7 event. In addition, winds during this latter event were more "gusty", and in general, the system appears to have been more energetic. The nephelometer records for these two events (Fig. 4.4.1-1a) indicate that significant levels of resuspension persisted for longer following the Day 7 event (approximately 20 hours compared to approximately 10 hours for Day 3).

Differences in wind duration and energy are reflected in the relative magnitudes of the wave and wind driven currents generated during each of the storm events. At equivalent peak velocities, long duration favors the generation of larger amplitude, longer period surface waves and increases the velocity and definition of stress-induced currents. Combined, both factors contribute to the total velocity and field differences, therefore, will appear as variations in peak current speeds. Such variations are evident in the current meter observations (Fig. 4.4.1-1b). These data show that maximum near bottom currents during the Day 7 event were approximately 20% higher than those observed during Day 3 and were nearly 10% higher than the next highest speed recorded during the deployment period. In the absence of significant streamflow induced currents, the consistency of these data favors the selection of storm duration as the factor responsible for the marked differences between the

Day 3 and Day 7 events. More detailed specification, including evaluation of the relative role of wind waves versus stress induced currents and the importance of seasonal or biological factors must await acquisition of high resolution current measurements and longer term data. Subsequent deployments were intended to satisfy this latter requirement.

4.4.2 Deployment No. 2 January 31, 1980 - March 3, 1980

Following replacement of the required batteries, films and data tapes, the instrumentation array was redeployed adjacent to the New London Disposal Site at the same location occupied during Deployment No. 1. Again, all instruments were sampled four times an hour. All instruments deployed were identical to those included on Deployment No. 1 with the exception of the pump assembly which was removed and returned to the manufacturer for repair and modification. The data obtained during this deployment are presented in Figures 4.4.2-1 to 4.4.2-4.

As in the case of Deployment 1, suspended material concentrations during the second deployment remained low, with average values varying between 2.5 and 3.5 mg/l (Figs. 4.4.2-1a and 4.4.2-1b). These concentrations displayed aperiodic perturbations sufficient to increase the near bottom values to approximately 16 mg/l. All of these perturbations were short lived with persistance times of less than 10 hours. These short time scales suggest that the majority of these events were the result of sediment placed in suspension by dredge material disposal operations rather than by wind waves or tidal currents. In early February 1980, the disposal site for sediment being

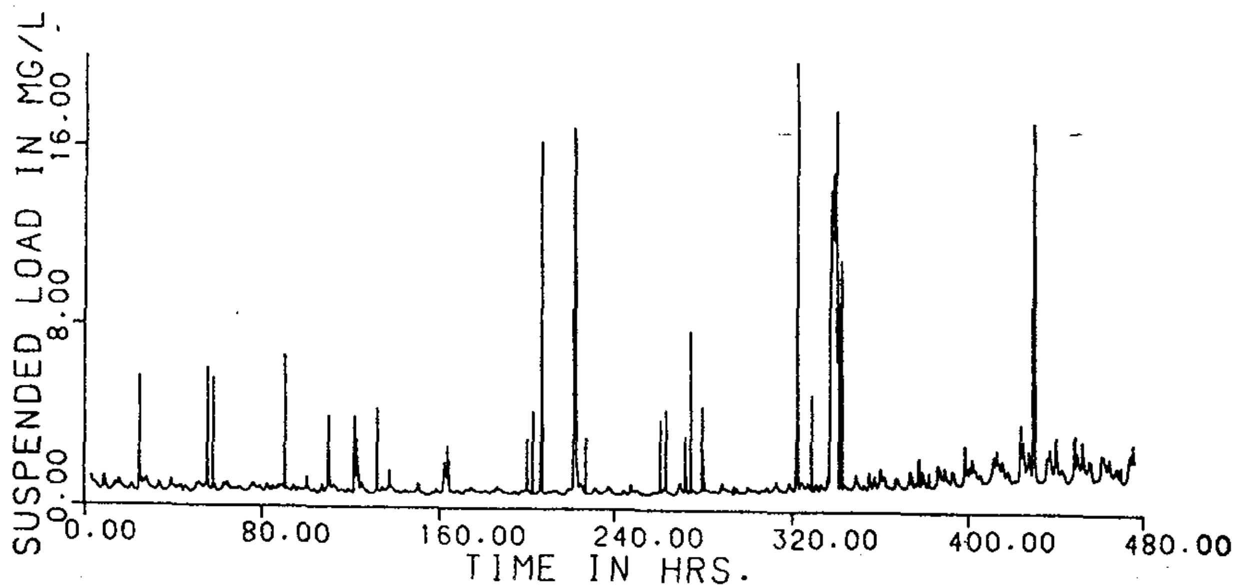


FIGURE 4.4.2-1a Suspended Material Concentrations
Nephelometer 1 - Deployment No.2

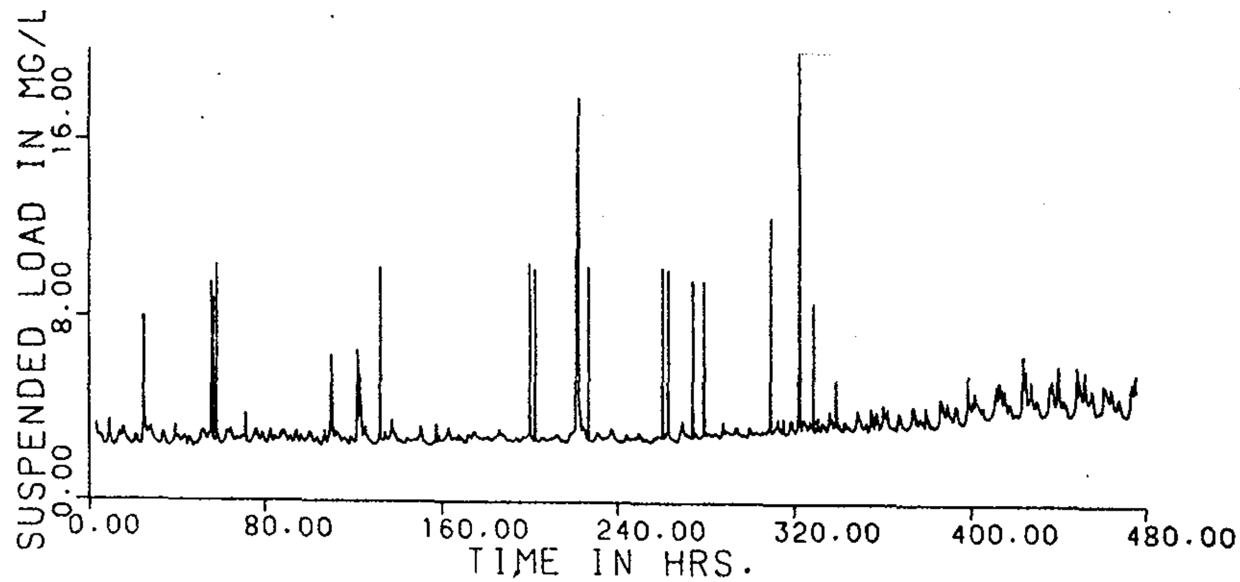


FIGURE 4.4.2-1b Suspended Material Concentrations
Nephelometer 2 - Deployment No.2

dredged from the lower Thames River was shifted from a location approximately 1.9 km east of the array to one located approximately 2.2 km north of the array. Given the characteristic currents affecting the study area, sediments introduced into the water column by disposal operations at the latter location will be advected past the instrumentation array during the ebb tidal phase. Previous investigations have shown that this cloud of sediment remains quite coherent and well-defined during transport with horizotal dimensions varying as a function of water depth and sediment type (Gordon, 1974).

Considering the water depths prevailing at the New London Disposal Site, these observations suggest that the cloud of sediments produced by disposal of fine grained Thames River sediment would have a characteristic horizontal extent of 200 to 400 m. With near bottom velocities ranging from 15 to 25 cm/sec (Fig. 4.4.2-2b), this cloud would tend to move past the instrumentation array in approximately 30 minutes. Array sampling rates of 4 scans per hour would therefore provide up to two samples of the dispersing sediments producing a short, well defined pulse in the optical data. The majority of perturbations observed in the nephelometer records (Figs. 4.4.2-1a and 4.4.2-1b) display these characteristics and, therefore, most likely reflect disposal activity.

In addition to the extremely short lived, disposal-related perturbations, several longer period resuspension events occurred during Deployment 2. These appear as peaks on the

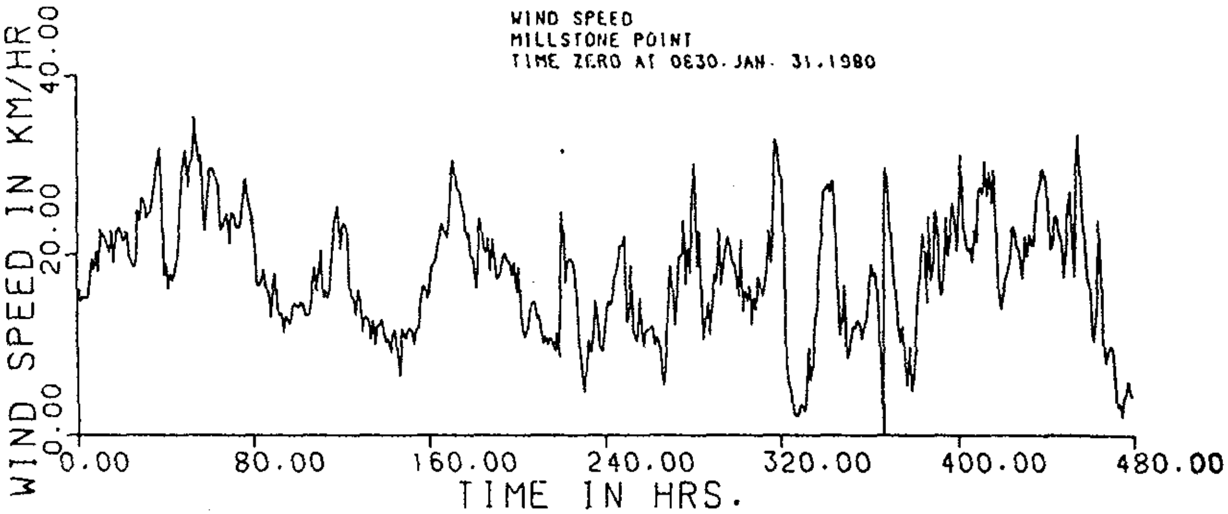


FIGURE 4.4.2-2a **Wind Speeds At 10m Elevation**

Deployment No.2

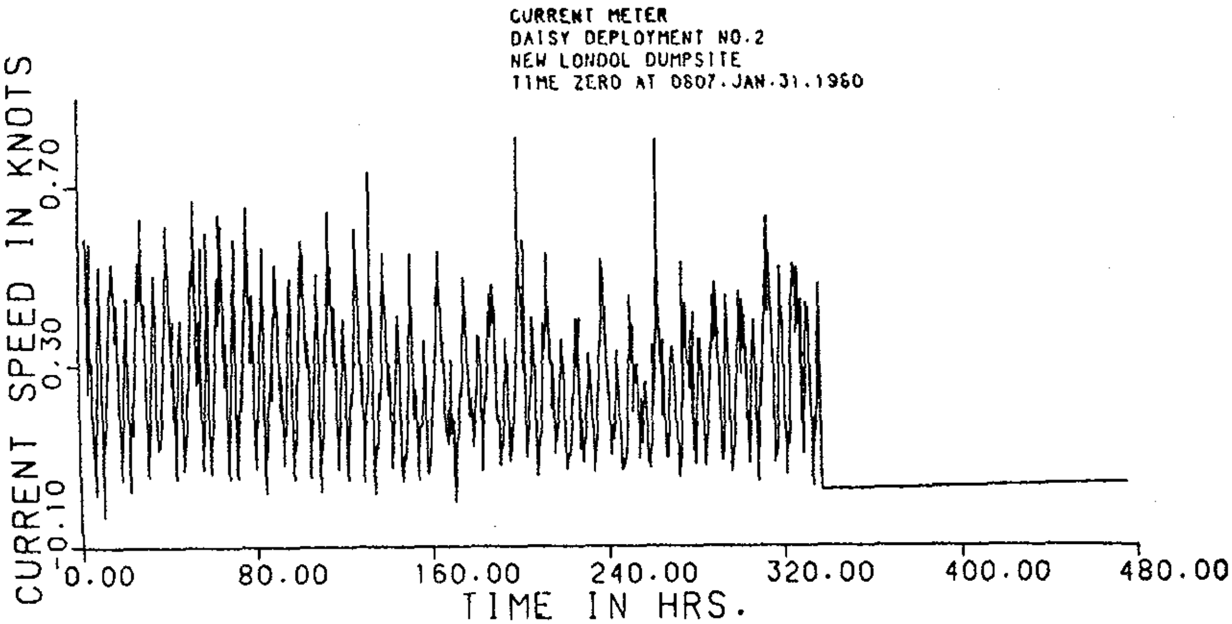


FIGURE 4.4.2-2b **Near Bottom Current Speeds**

Deployment No.2

nephelometer records (Figs. 4.4.2-1a&b) during Day 2 (~25 hrs), Day 3 (~57 hrs), Day 5 (~120 hrs), Day 9 (~225 hrs), and Day 13 (~320 hrs). None of these events persist for more than five hours and several appear to represent a superposition of naturally induced and disposal related suspension. In no case are these events as well defined as those observed during Deployment 1. There appear to be two primary reasons for this.

First, and of primary importance, wind stress levels for Deployment 2 are substantially lower than those prevailing during Deployment 1. Peak wind velocities during February 1980 seldom exceeded 30 km/hr (Fig. 4.4.2-2a) and the few well defined events all displayed durations of less than 24 hours. Given the response characteristics established during the first deployment, it is not surprising that these events produced only minor increases in suspended material concentration.

Second, stream flows during the February deployment were higher than those prevailing during January. As a result, conductivity levels in the study area displayed significant variability (Fig. 4.4.2-4) sufficient to indicate stratification of the water column resulting from cold, fresher water from the Thames River impinging on the disposal site. Such stratification, in part, isolates near bottom waters from surface activity, therefore, requiring increased energy inputs to disturb the sediment water interface. This factor, in combination with lower wind stress levels, favors reduced resuspension and an apparent increase in sediment stability, which is reflected in the data obtained during Deployment No. 2.

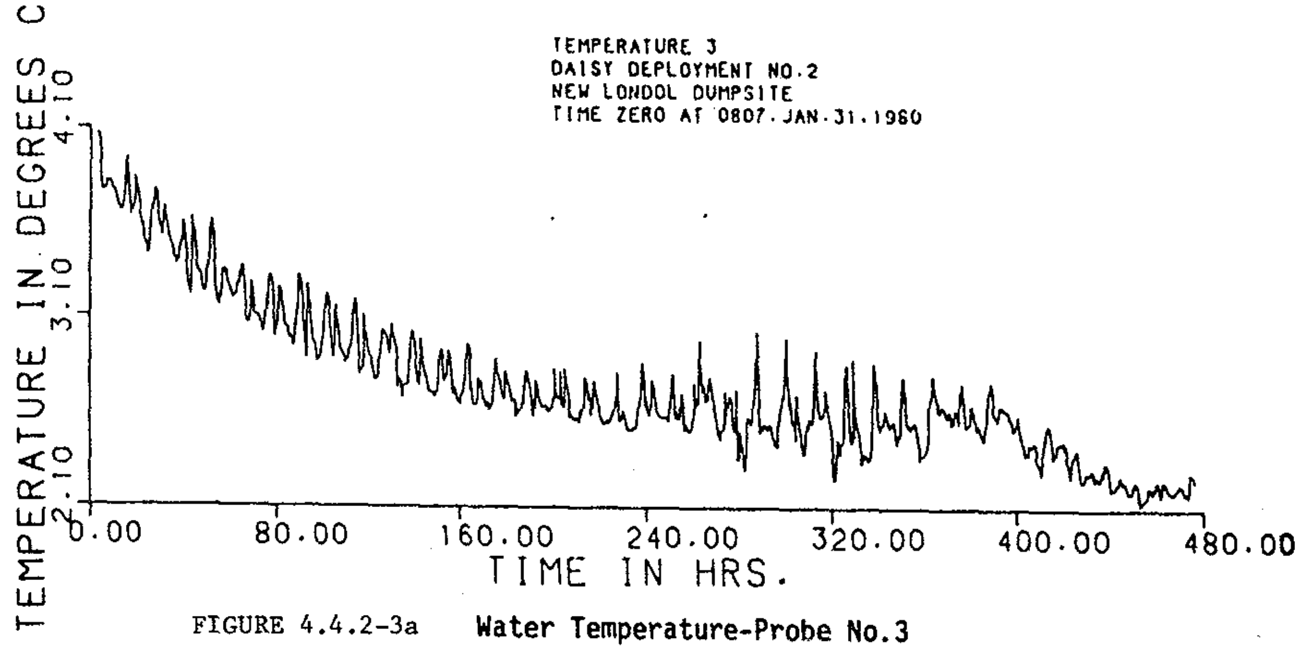


FIGURE 4.4.2-3a **Water Temperature-Probe No.3 Deployment No.2**

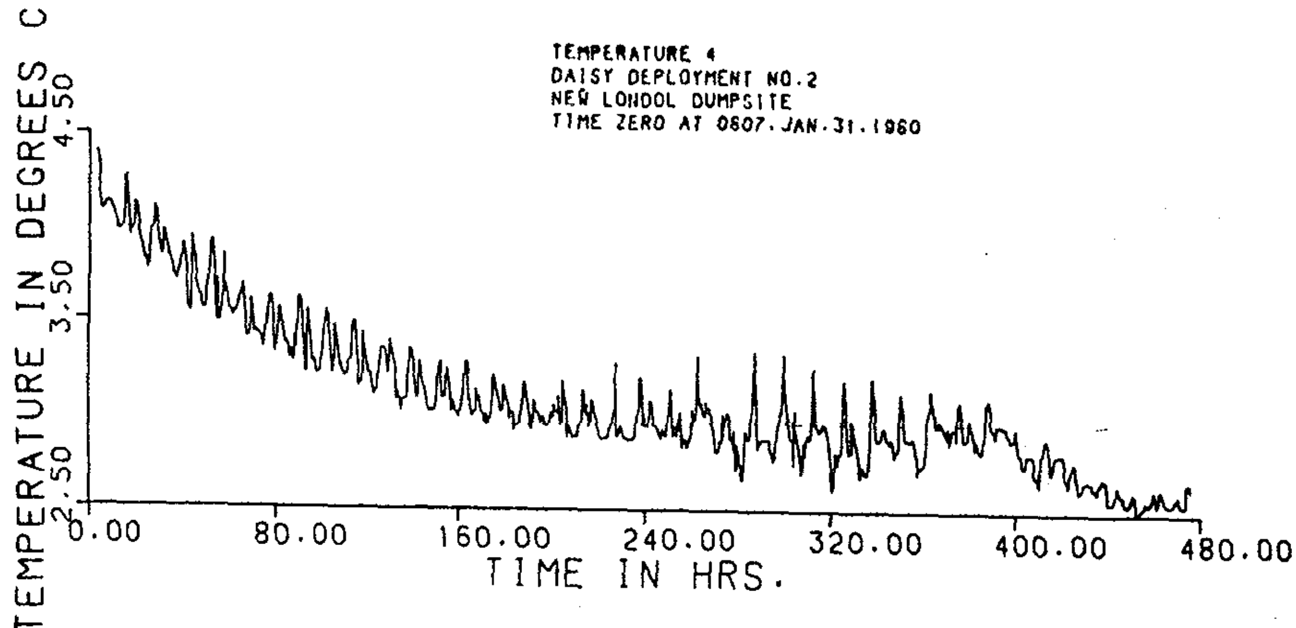


FIGURE 4.4.2-3b **Water Temperatures-Probe No.4 Deployment No.2 .**

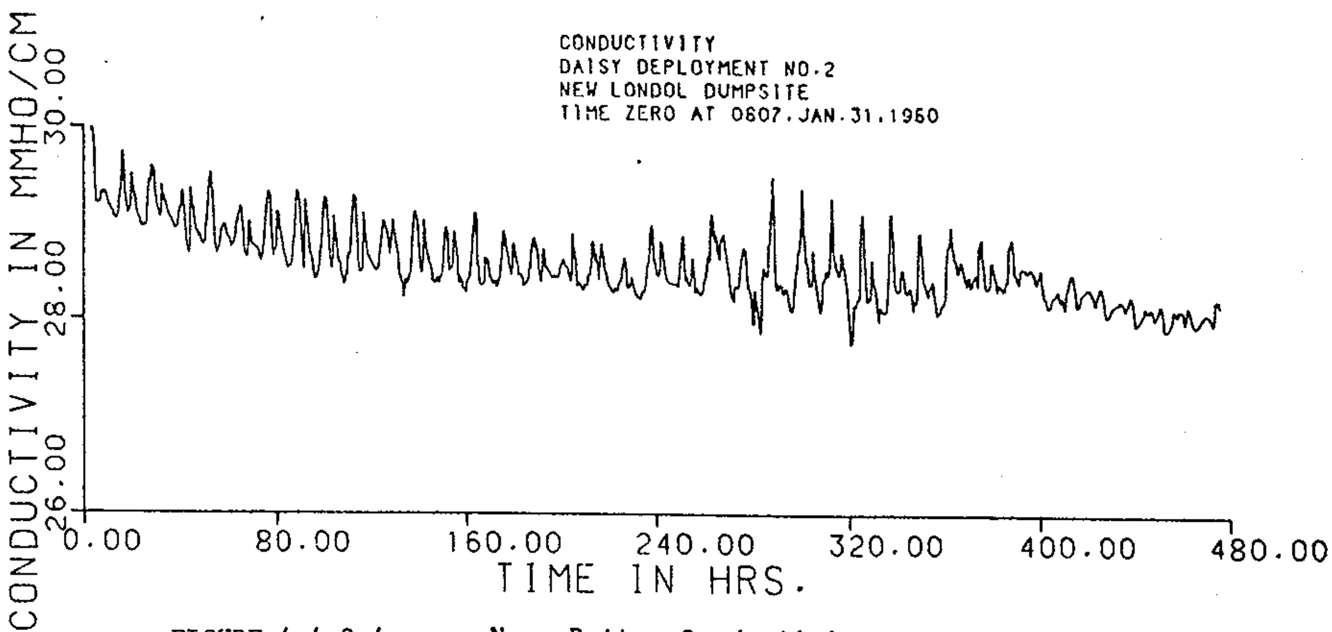


FIGURE 4.4.2-4 Near Bottom Conductivity Deployment No.2

4.4.3 Deployment No. 3 March 17, 1980 - April 18, 1980

During the third deployment the instrumentation array was again located adjacent to the New London Disposal Site in approximately 20 m of water. The sampling routine was identical to that followed in the initial two deployments and the instrumentation package was identical to that used in Deployment No. 2 since the pump assembly remained at the manufacturer for modification.

The data obtained during Deployment 3 indicate a slight increase in average suspended material concentrations over the levels observed in the previous two deployments. Average values varied between 3.0 and 4.0 mg/l and displayed a progressive increase over the deployment period (Figs. 4.4.3-1a&b). The major portion of this increase, particularly after 480 hours, may be attributed to accumulation of material on the optical windows. The effects of biological factors, including fouling and increased organic content or productivity, appear to be negligible.

Periodic increases in suspended material concentration (to approximately 20mg/l) are easily visible against the background variation for each tidal cycle (Figs. 4.4.3-1a&b). These perturbations are, however, short lived and, as in the case of Deployment 2, appear to be the result of sediment suspension associated with dredged material disposal rather than naturally occurring instabilities of the sediment water interface. For such perturbations, simple tidal advection appears to be the governing transport mechanism.

In addition to the disposal related perturbations, the optical data indicate that several longer period variations also

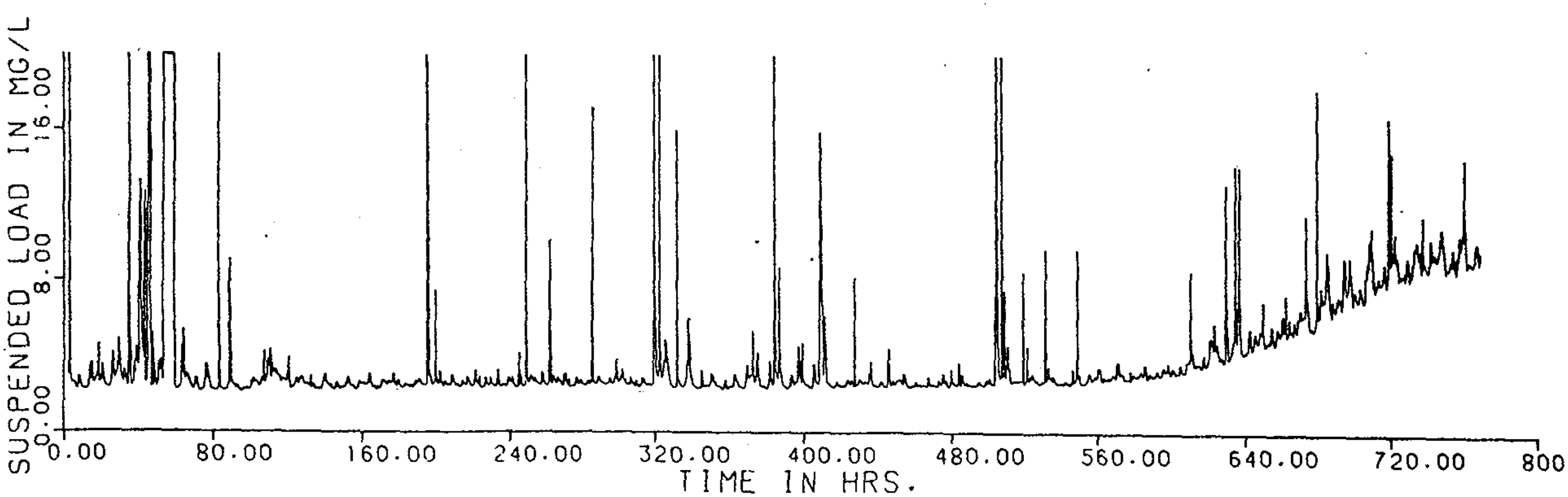


FIGURE 4.4.3-1a Suspended Material Concentrations
Nephelometer 1 - Deployment No.3

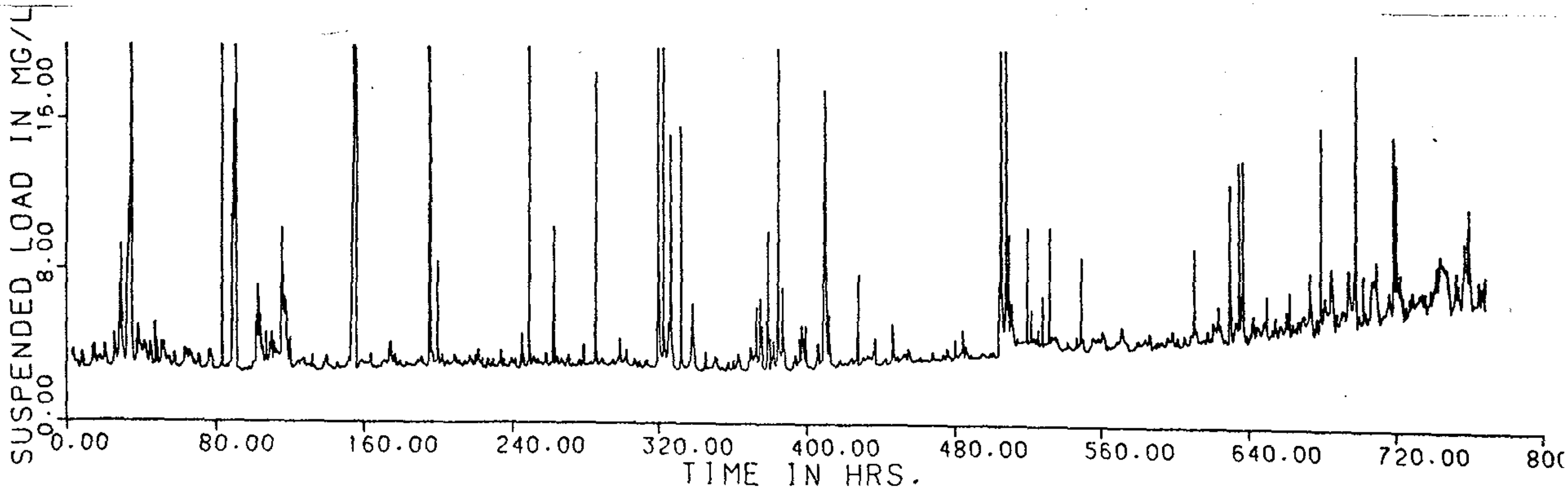


FIGURE 4.4.3-1b Suspended Material Concentrations
Nephelometer 2 - Deployment No.3

occurred during Deployment 3. Unfortunately, most of these events are contaminated by concurrent disposal operations and are difficult to analyse. A particularly clear event, however, did occur on Day 4 (~100 hrs) with concentration levels increasing to 5-8 mg/l over a period of approximately 20 hours. This increase appears to be primarily the result of wind induced resuspension. Since stream flows during the deployment period were relatively low favoring near constant salinity levels (Fig. 4.4.3-2b) and minimal vertical stratification.

Concurrent wind records obtained at a shore based station (Fig. 4.4.3-2a) indicate that a high intensity wind event occurred over Day 4 with peak speeds in excess of 50 km/hr. These high winds, rich in easterly components, persisted for approximately 50 hours and were observed to generate waves having length and amplitude obviously sufficient to increase energy levels at the sediment water interface. This event is similar in character to those observed during Deployment 1 with increases in suspended material concentrations appearing as a series of discrete peaks. Although failure of the current meter during this deployment precludes simple comparison with tidal state, these peaks are separated in time by approximately 6 hours or a half tidal period. The pattern again seems characteristic of a system in which resuspension requires the combined energies of both waves and tidal currents. Acting separately, these factors produce relatively small increases in suspended material concentration.

4.4.4 Deployment No.4 June 6, 1980 - July 10, 1980

The initial three deployments were intended to provide

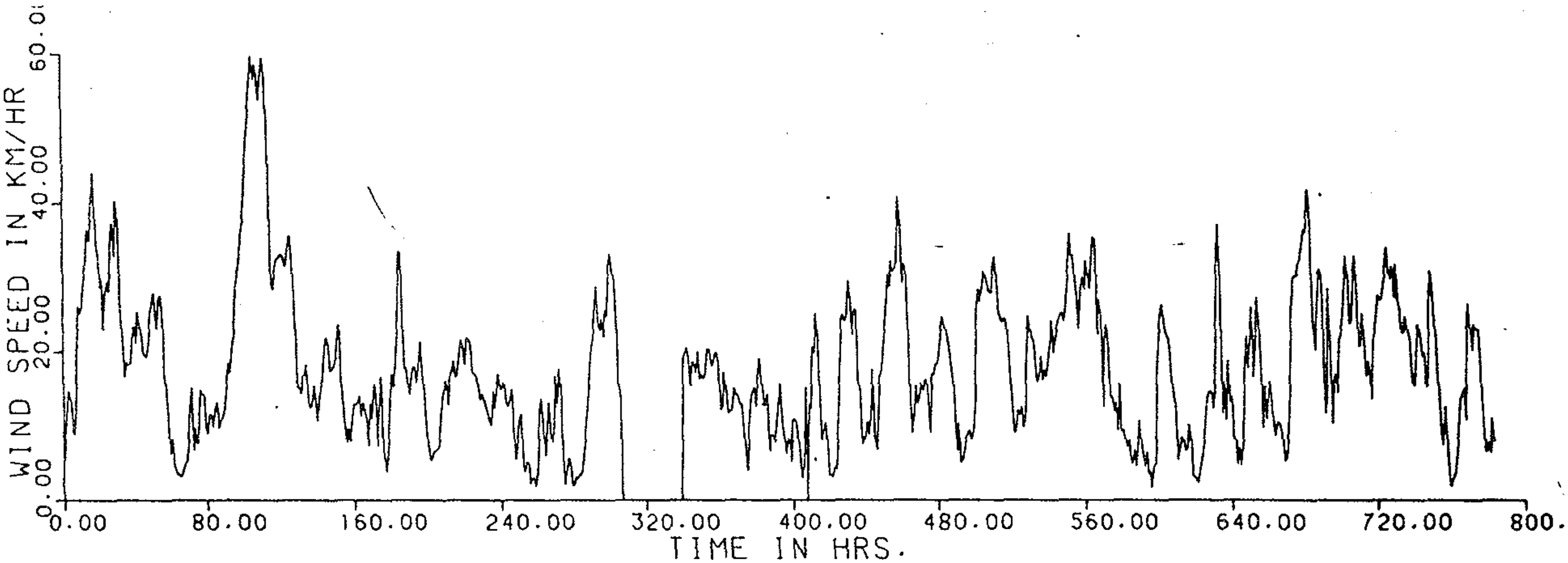


FIGURE 4.4.3-2a Wind Speeds At 10m Elevation

Deployment No.3

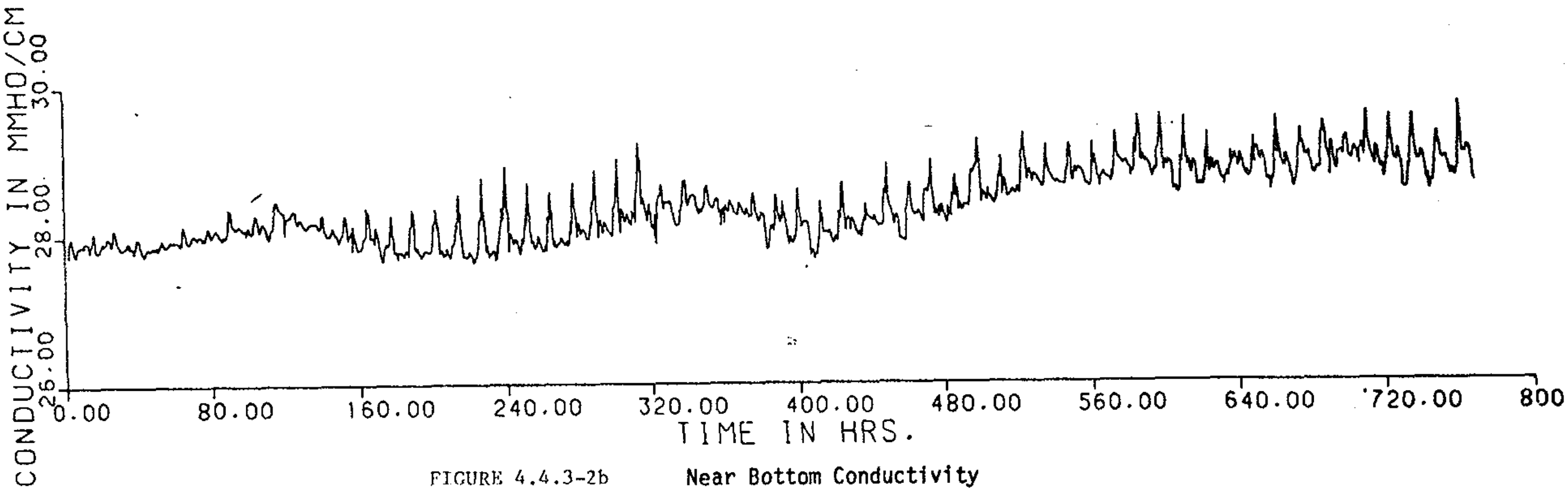


FIGURE 4.4.3-2b Near Bottom Conductivity

Deployment No.3

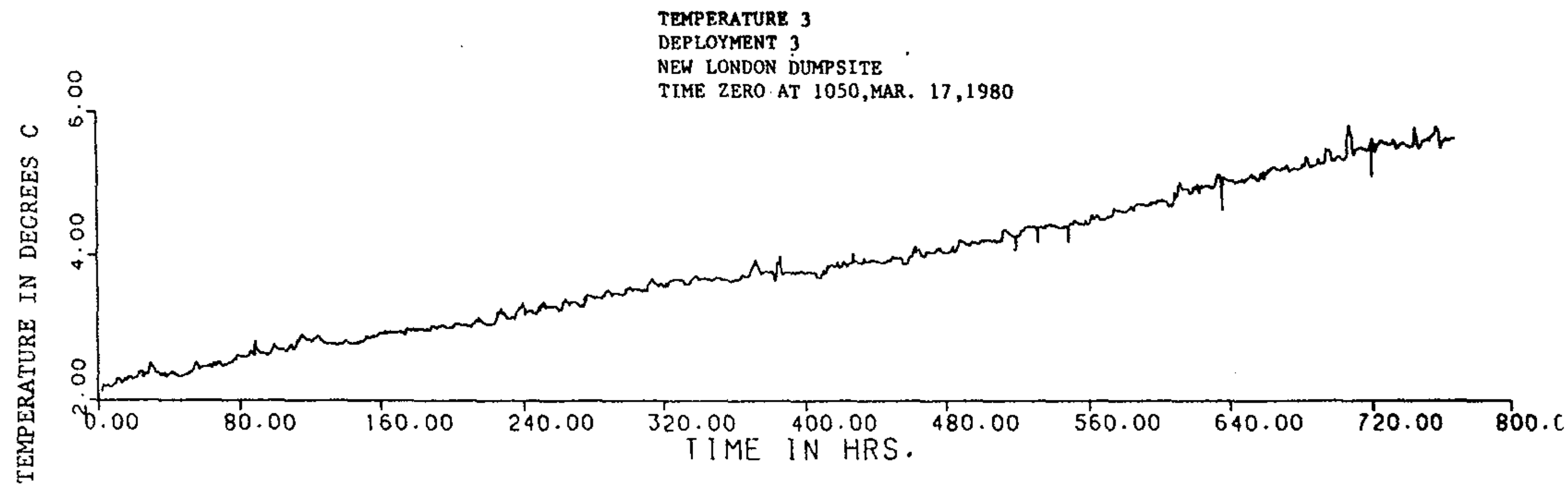


FIGURE 4.4.3-3a Water Temperatures-Probe No.3
Deployment No. 3

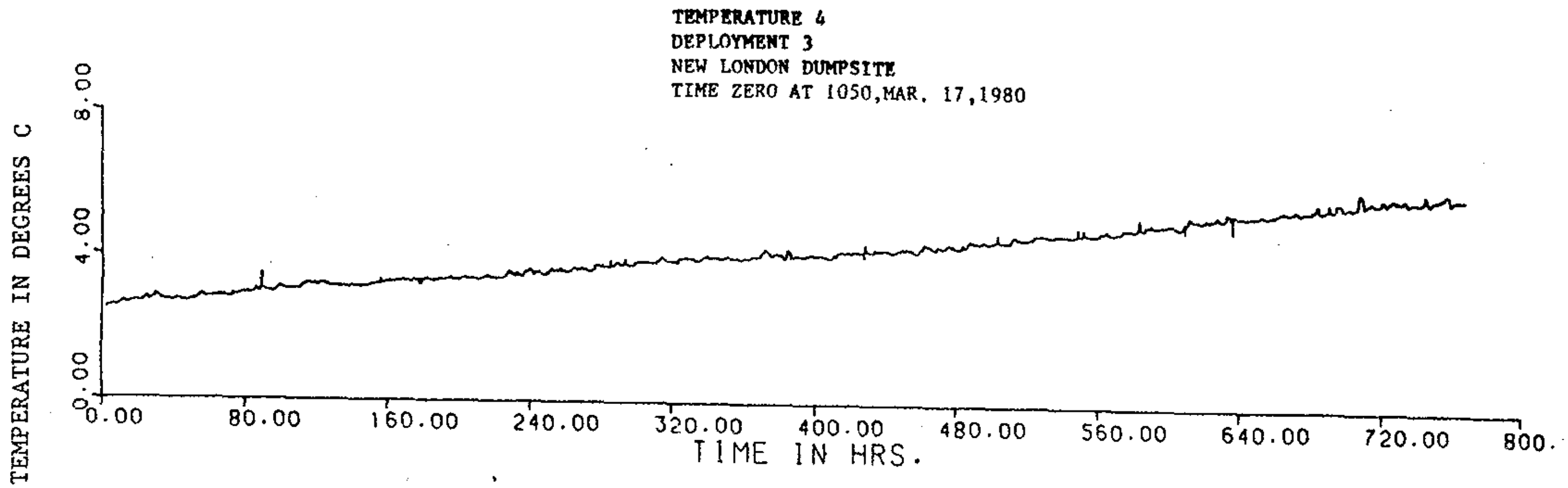


FIGURE 4.4.3-3b Water Temperatures-Probe No.4
Deployment No. 3

observations of the response characteristics of the suspended material field in Eastern Long Island Sound during the high energy periods typically prevailing in the later winter and early spring. The fourth deployment, commencing on June 6, 1980, was intended to provide some contrasting data by observing response under more quiescent, early summer conditions. The study site remained located along the western margin of the New London Dumpsite and array sampling rates were identical to those used in Deployments 1 through 3. The instrument assembly was identical to that used during Deployments 2 and 3 with the addition of the pump filtration unit which returned from the manufacturer in time to be briefly lab tested, fitted with filters, and mounted on the frame. The data obtained during this deployment are presented in Figures 4.4.4-1 through 4.4.4-4.

Deployment No. 4 was severely affected by intense biological fouling of the frame and all subsystems. As is evident in most of the data records, particularly the optical (Figs. 4.4.4-1a&b), and current meter data (Fig. 4.4.4-2b), this fouling began soon after immersion of the frame and advanced slowly during the first ten days of deployment (~240 hrs.). After that time, the amount of fouling increased precipitously and within a relatively short period rendered the array inoperative. This rapid increase appears to have been caused by the settling, attachment and subsequent growth of a hydroid colony. These animals have a free drifting medusal stage, and following attachment to a suitable substrate, form a dense shrublike growth. Upon recovery, such growth was evident over virtually the entire frame.

Prior to the onset of intense fouling, the instrumentation array did provide reasonably accurate data for a period of approximately 10 days (June 6 - June 16, 1980). Concentrations of suspended materials during this time displayed average values similar to those observed during Deployment 1. These values varied between 2.0 and 3.0 mg/l with an evident periodicity correlated wih the tidal cycle (Figs. 4.4.4-1a&b and 4.4.4-2b). These tidally associated variations appear to be somewhat larger than those observed during previous deployments, displaying concentrations from 30 to 50% over the baseline. A plausible explanation for this increase in resuspension is that it was related to an increase in biological activity sufficient to either actively or passively destabilize the sediment water interface. A variety of diver observations suggest that such activity is common particularly during the summer months (Stewart, personal communication). More specific information on the influence of biological activity on sediment stability requires more detailed observations than are presently available.

In addition to the tidal variations, suspended material concentrations also diplay a variety of larger amplitude, aperiodic perturbations. Of these, only the event occurring on Day 3 ($\sim$72 hrs) appeared to have been produced, a least in part, by a significant wind event. Peak winds during this event exceeded 30 km/hr for a period of approximately 30 hrs. (Fig. 4.4.4-2a). Although previous observations suggest that these characteristics are barely sufficient to induce resuspension, this event does appear to have been able to induce a factor of two increase in near bottom concentrations. The magnitude of this increase, despite the lower energy level wind event, suggests that

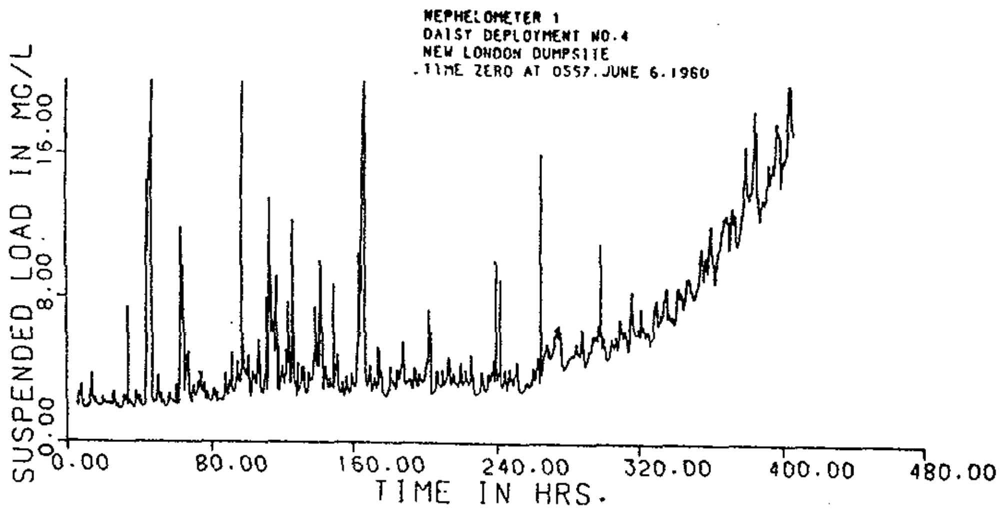


FIGURE 4.4.4-1a Suspended Material Concentrations
Nephelometer 1 - Deployment No.4

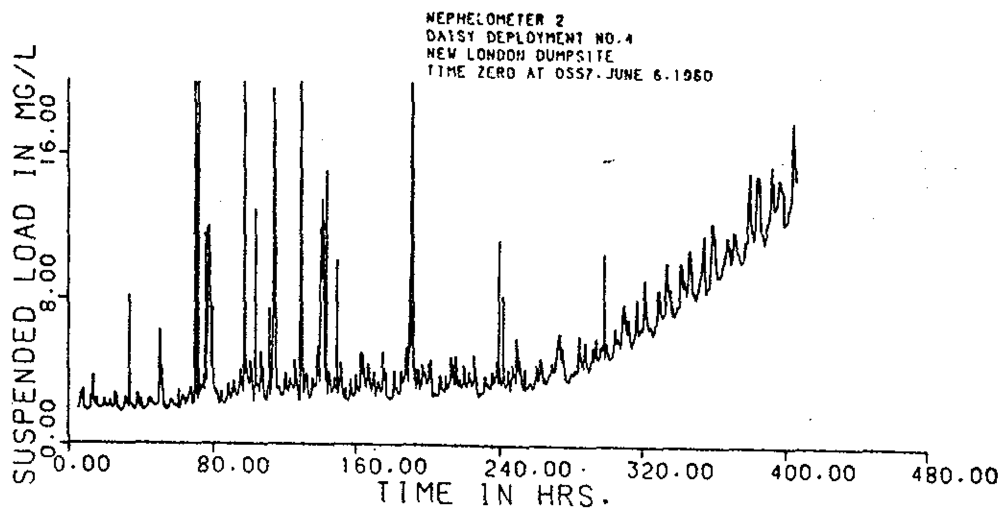


FIGURE 4.4.4-1b Suspended Material Concentrations
Nephelometer 2 - Deployment No.4

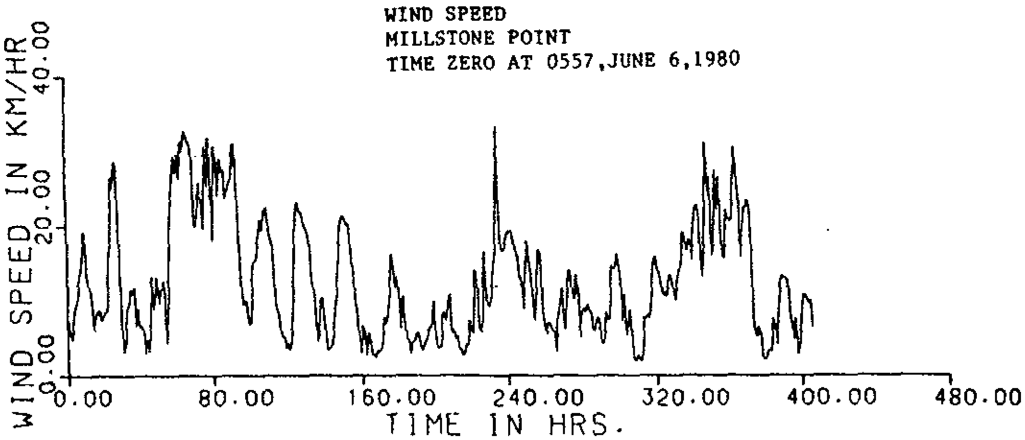


FIGURE 4.4.4-2a **Wind Speed At 10m Elevation**

Deployment No.4

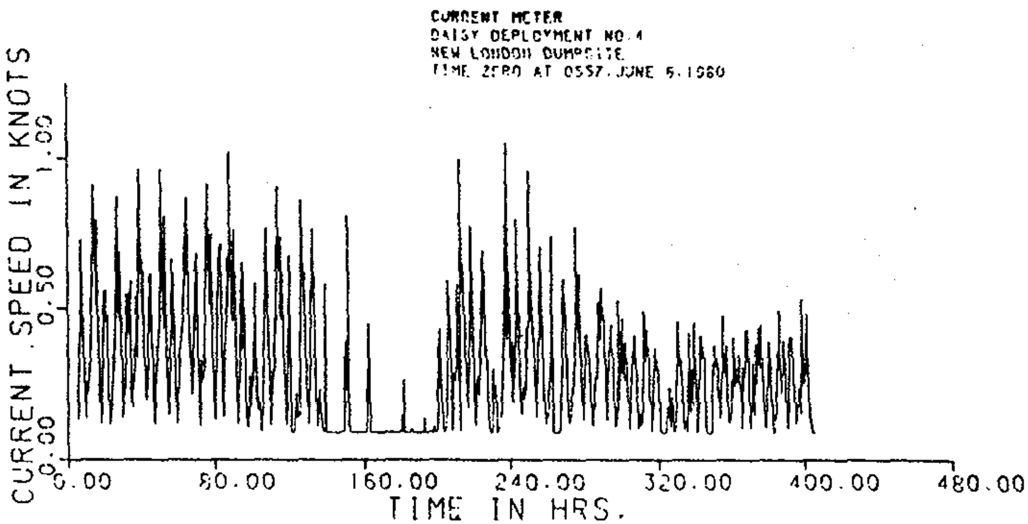


FIGURE 4.4.4-2b **Near Bottom Current Speeds**

Deployment No.4

the inherent stability of the sediment-water interface declined during this period relative to the previous deployment periods. Again, this may be attributable to increased local biological activity.

The remaining suspended material perturbations appear to be the result of resuspension associated with dredge material disposal possibly combined with clouds of locally produced organic material, such as the medusal hydroids, being advected past the instrumentation array. The biological factor is suggested for two reasons. First, the dredging contractor's records indicate that disposal from the lower Thames River was terminated on June 10, 1980 (~Day 4 of the observation period). Aperiodic peaks persist after this date although at a somewhat lower frequency. Second, the character of the peaks is somewhat different than that displayed by perturbations occurring during the first three deployments. In particular, many of the perturbations observed during Deployment 4 display a persistence that is significantly greater than that previously associated with disposal related resuspension. Increasing duration suggests either large diameter suspension clouds or the presence of other turbidity inducing factors. Since there is no reason to assume that the cloud of sediment produced by disposal should be much larger than previous operations, increased duration must be caused by the presence of other factors. Local biological productivity appears to represent the most reasonable explanation given the season, observed fouling rates, and the general absence of significant stream flow related inputs.

The composition of the suspended material load could not

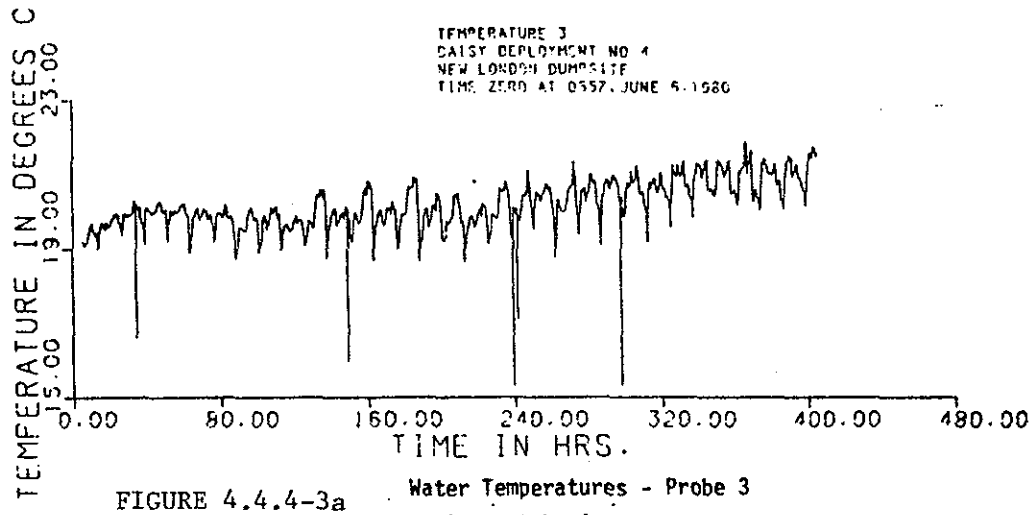


FIGURE 4.4.4-3a Water Temperatures - Probe 3
Deployment No.4

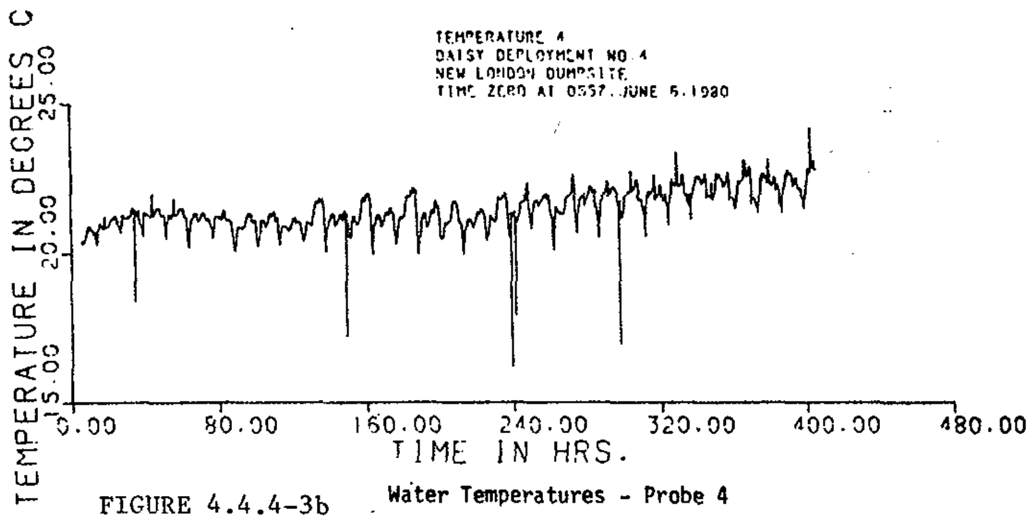


FIGURE 4.4.4-3b Water Temperatures - Probe 4
Deployment No.4

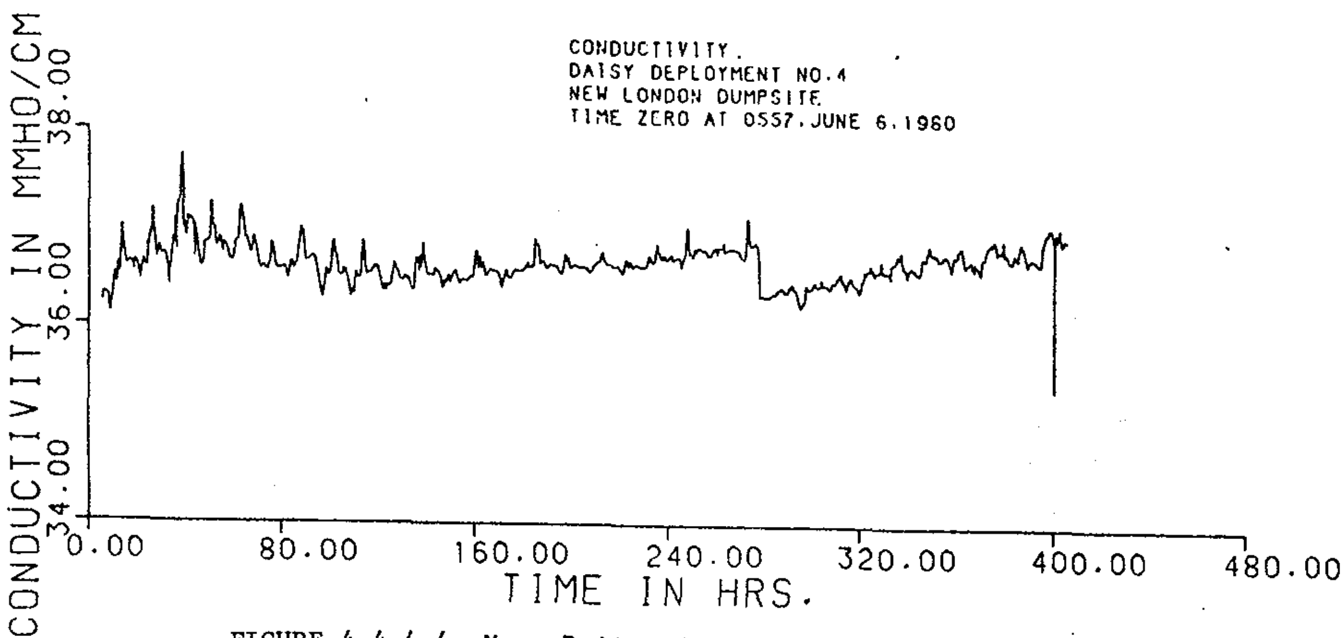


FIGURE 4.4.4-4 Near Bottom Conductivity
Deployment No.4

be clearly ascertained, since the optical data are non specific and direct samples were not collected. The pump-filtration unit included in the array was intended to provide a means to determine the composition of the suspended load. This unit failed shortly after deployment and did not provide any useful data. This unit is to be replaced with a completely modified system during the Fall of 1980. Characterization of the suspended load is considered central to the resolution of the questions concerning the effects of biological activity and/or associated disposal material resuspension.

4.5 Summary

The data provided by the initial series of array deployments indicate that the sediment-water interface in the vicinity of the New London disposal area experiences a variety of disturbances sufficient to induce measurable resuspension. Over an average tidal cycle, near bottom suspended material concentrations display a regular variability in phase wih the local tidal currents. The magnitude of these variations varies seasonally, ranging from approximately 10% during the late winter months to 30% in early summer. The seasonality in substrate stability appears to be the result of variations in biological activity although at present this cannot be easily determined in the absence of a long term series of observations.

In addition to tidally induced variations, near bottom suspended material concentrations are perturbed aperiodically by high energy storm events. Several of these events occurred during the period of observation. All were primarily wind dominated events and were accompanied by negligible increases in local streamflow. Analysis of the response of the suspended material field indicates that only those events characterized by wind speeds of 40 km/hr or more, and durations in excess of 40 hours are sufficiently energetic to induce significant resuspension. These characteristics suggest that the primary effect of the storm is realized though the surface wave field with wind stress induced currents playing a secondary role. Suspended material response also indicates that these waves act in combination with local tidal currents favoring maximum resuspension during periods of peak tidal velocity. These features illustrate the importance of wave current interactions to sediment transport in Eastern Long Island Sound. Analyses of inherent sediment erodibility or stability in this area must therefore include consideration of this combined factor.

In summary, the initial series of observations show the sediment water interface in the vicintiy of the New London disposal area to be in near equilibrium with average flow conditions. Increasing flow energy above 'ambient' levels will induce immediate resuspension sufficient to increase near bottom concentrations by a factor of 3 to 5. Such increases appear to be primarily confined to periods of high wind stress favoring generation of large amplitude, long period surface waves and their subsequent interaction with the local tidal velocity field. Overall, there is a suggestion that resuspension magnitude varies seasonally in response to biological activity. This factor, however, cannot presently be evaluated. It is expected that it will be considered in more detail during subsequent deployments.

5.0 CHEMISTRY OF SURFACE SEDIMENTS

5.0 Chemistry of Surface Sediments

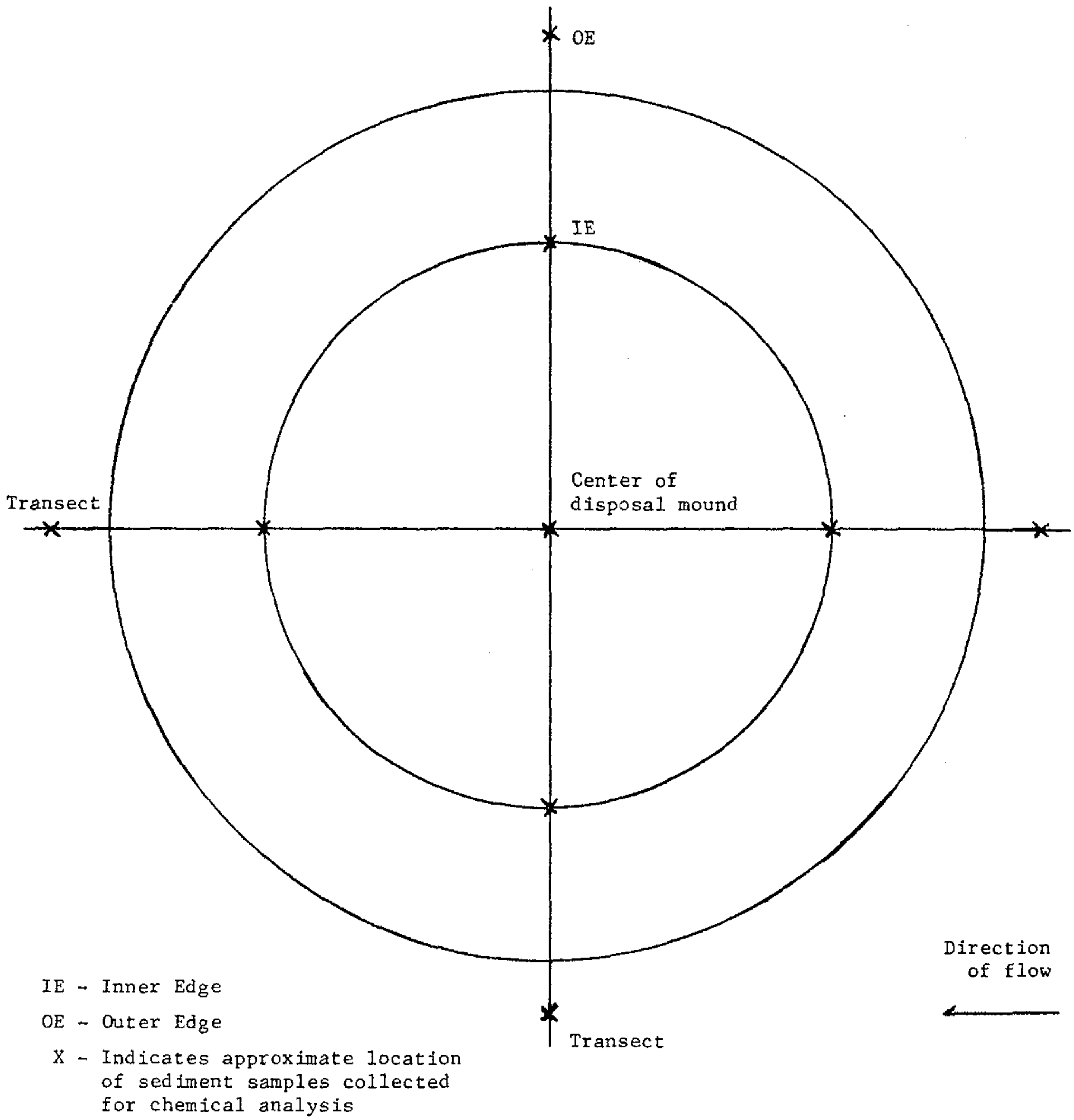
5.1 Introduction

Bulk chemical analyses of dredged material at disposal sites throughout the New England region continued as a major portion of the DAMOS program during 1980. As in most other aspects of the program, changing priorities resulted in an emphasis on sampling at the Portland, New London and Central Long Island Sound Disposal Sites while sampling ceased at other locations.

The major objectives of the chemical sampling program are to provide a tool for assessing the distribution and stability of dredged material at each disposal site, and to estimate the contaminant load available for biological uptake. Therefore, the sampling scheme employed at each site was designed uniquely to suit conditions prevailing in that site. The basis for sampling was a "cross" distribution with one transect established parallel to the current flow at the site and the other perpendicular to the flow (Figure 5.1-1). Actual sampling locations along each transect were determined by the distribution of dredged material, which was ascertained by bathymetry, diver observations and visual inspection of sediment samples. At all sites, at least one station was established at the center of the disposal area to obtain a measure of the contaminant load of the dredged material. On each of the four legs of the transects two stations were then established, one on the apron of the disposal mound, generally characterized by fine-grained, unconsolidated dredged material, and one on natural bottom close to the margin of

5.1-1 Diagram of a theoretical disposal site indicating location of sediment samples collected for chemical analysis

X Reference



the dredged material. By comparing "inner" and "outer" edge samples, spreading of dredged material could then be detected and the potential availability of contaminants to benthic organisms in the immediate vicinity of the disposal site, evaluated.

In addition to these stations, chemical samples were also obtained from the biological reference station which was established on a similar natural bottom in an area remote from, and presumably unaffected by, the disposal operation.

Previous reports have discussed several properties of the heavy metal concentration data which appear to be fairly consistent in the New England region (DAMOS Annual Data Report, Vol.I, Physical Observations). In general, samples with higher concentrations tend to display greater variability, and metal concentrations tend to increase or decrease as a group, although the magnitude of difference varies for individual metals. As in the last DAMOS report (Vol.I, 1979), copper (Cu) data are presented and discussed as being representative of the general chemical properties of dredged material. All other metal data for the samples discussed here have been analyzed and will be presented in future data reports.

5.2 Portland Disposal Site

The Portland Disposal site was surveyed in April, 1980 using the "cross" transect pattern. The site is a narrow (200-300 m wide) gully located in 60 m of water surrounded by rock outcrops which grade up to 40 m depths (Figure 2.3-2). The April survey revealed that disposed dredged material had completely covered the natural bottom in some directions. Consequently, the only 1980 sample collected from this site which was found to be free of dredge material was the "outer edge" sample on the north transect. The mean copper concentration for the entire disposal area was 34.4 ppm with a standard deviation of 5.9 ppm, which differed sharply from the 3.9 ppm mean concentration observed prior to disposal.

The Cu concentration levels currently occurring at the disposal site resemble, but are slightly lower than, those observed in the samples obtained from Portland Harbor. This slight observed decrease is probably the result of mixing during the dredging and disposal operation of the more highly contaminated surface material from the harbor with older, glacially-derived harbor sediments which are relatively uncontaminted.

5.3 New London Disposal Site

Prior to the March, 1980 survey, nine stations were sampled at the New London Disposal site. The sampling array consisted of six stations located along a NW-SE transect, two on a transect oriented orthogonally to the first (NE-SW) on either side of the center, and a reference station. Significant differences in Cu concentration were observed between "inner" and "outer" stations only. Those stations on the disposal mound were characterized by high sample-to-sample variability and mean Cu levels of about 20 ppm, compared to a mean of 10 ppm at the outer stations.

During the March 1980 survey, evidence of dredged material was found a considerable distance from the center of the disposal mound along the NS and EW transects. Therefore, in all subsequent surveys at New London, samples were collected along NS and EW transects at 300 m ("inner edge") and 600m ("outer edge") from the center. All samples taken out to 600 m along the NS, EW transects displayed elevated metal concentrations characteristic of disposed dredge material. An unusually high level of Cu was found in samples at the 300 m station to the east along the EW transect. The observed concentrations were more than three times higher than values measured at any other station. Similar concentrations had been found at station F-8 during the 1979 sampling period. Although these stations were not located at the same point, they were in the same general vicinity and the similarity in Cu levels suggests the sustained presence of a specific dredged material deposit over a period of time.

5.4 Central Long Island Sound Disposal Site

A major emphasis in the monitoring of the Stamford-New Haven disposal site was placed on the chemical analysis of sediment samples since the isolation of contaminated Stamford material was an important criterion for the success of the capping operation. In order to evaluate observed changes in concentration, a reproducible baseline was required. This was achieved in the Central Long Island Sound region where Cu concentrations in the baseline and reference samples averaged 70.6 ppm with a standard deviation of 13 ppm over the entire survey.

5.4.1 Stamford-New Haven North (STNH-North) Disposal Site

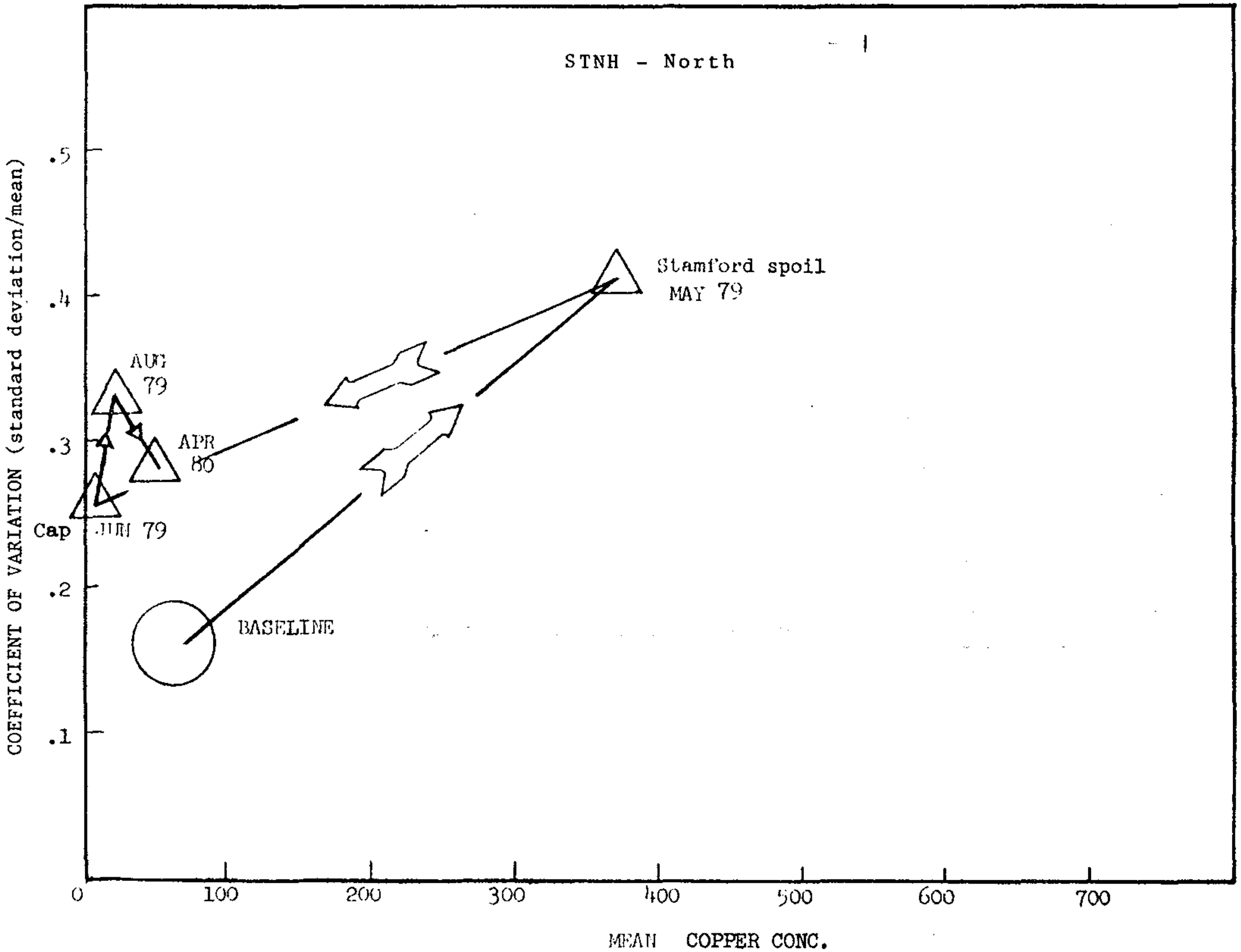
The STNH-North site was of particular importance in assessing the consequences of the capping procedure since no further disposal of Stamford dredged material occurred after placement of the cap in June, 1979. In addition, diver and bathymetric surveys indicated that the New Haven sand cap effectively covered the Stamford material, and that the topography of the mound remained relatively stable over the entire survey area through April, 1980. Chemical analyses, therefore, provided a reasonable measure of how effectively the cap contained the contaminated Stamford material.

Five separate sampling surveys were conducted at the STNH-North site between March, 1979, and April, 1980, as follows:

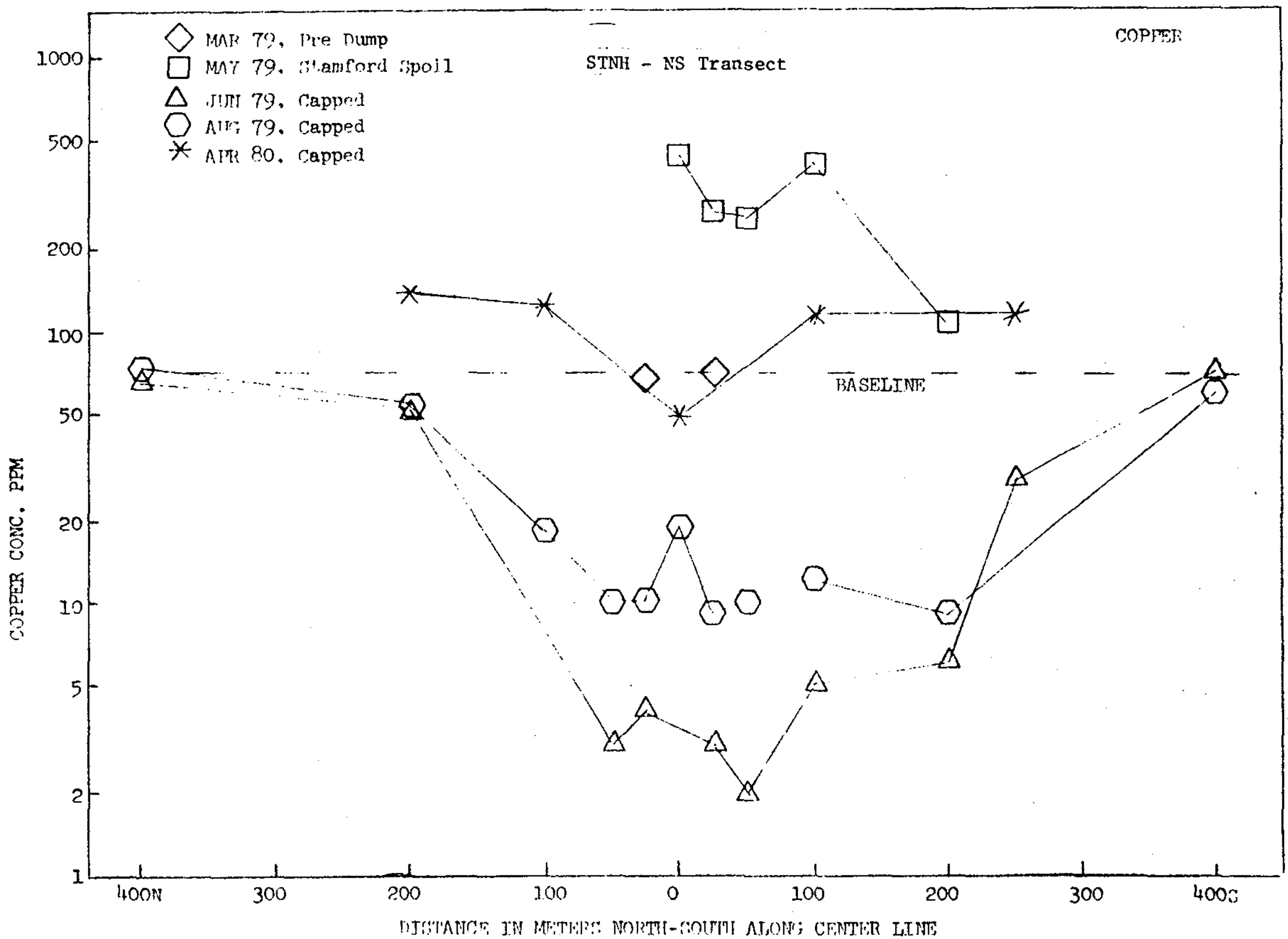
- March, 1979 - baseline survey
- May, 1979 - post Stamford disposal survey
- June, 1979 - post New Haven cap survey
- August, 1979 - post disposal survey
- April, 1980 - post disposal survey

This sampling schedule permitted observations on the evolution of the mound from initial disposal through the period of most intense storm activity (winter), until the pile began to resemble ambient sediment chemistry conditions.

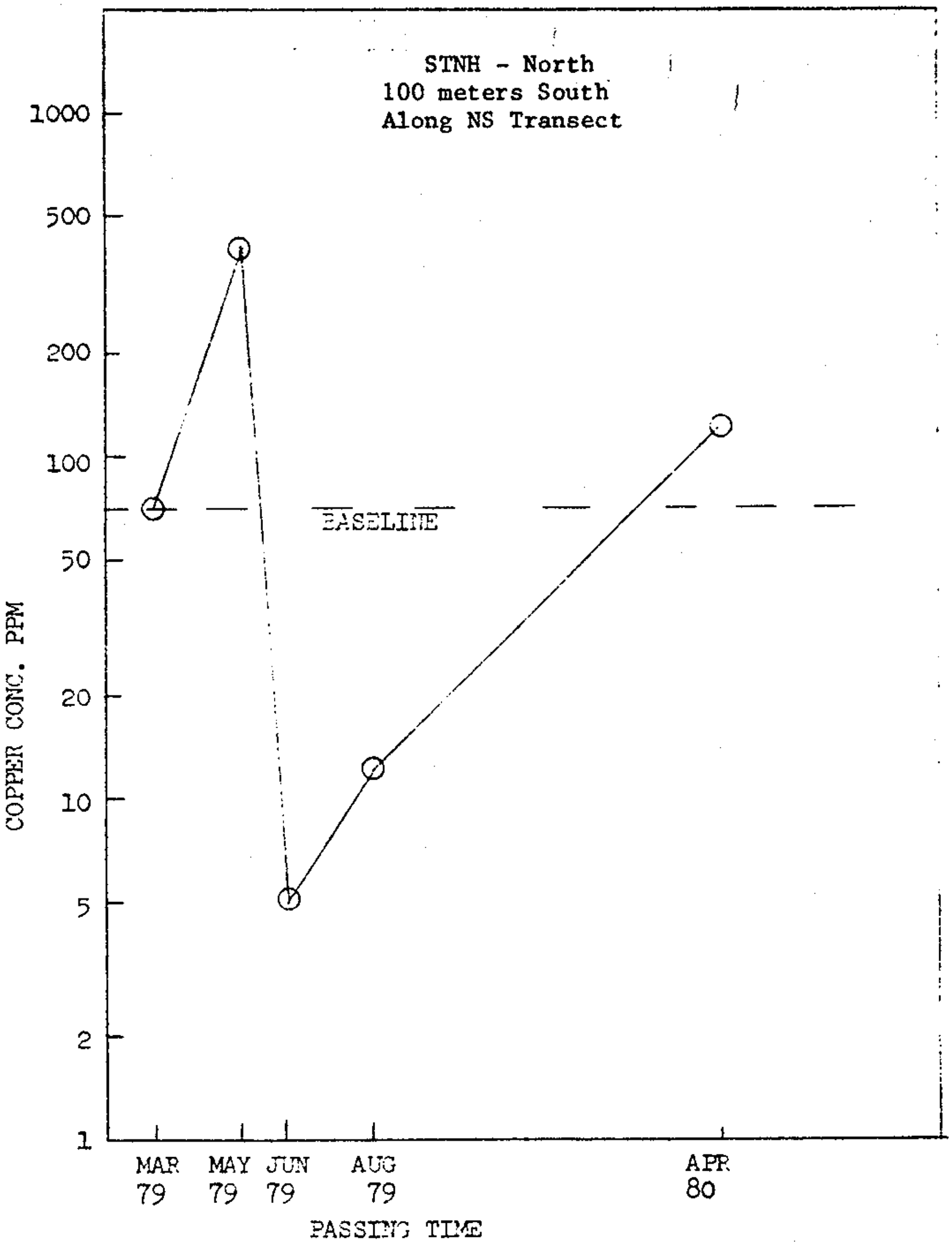
Figure 5.4.1-1 presents a summary of the changes in Cu concentration observed in the year of sampling at the STNH-North site. As stated earlier, when metal concentrations increase, the variability between samples tends to increase. The finding of local heterogeneity in chemistry data following disposal is fairly common and this property can be used to identify dredged material. The baseline data (pre-disposal survey, March, 1979) are characterized by relatively low concentrations, and more significantly, low variability between samples which is reflective of a relatively homogeneous, or stable, environment in equilibrium



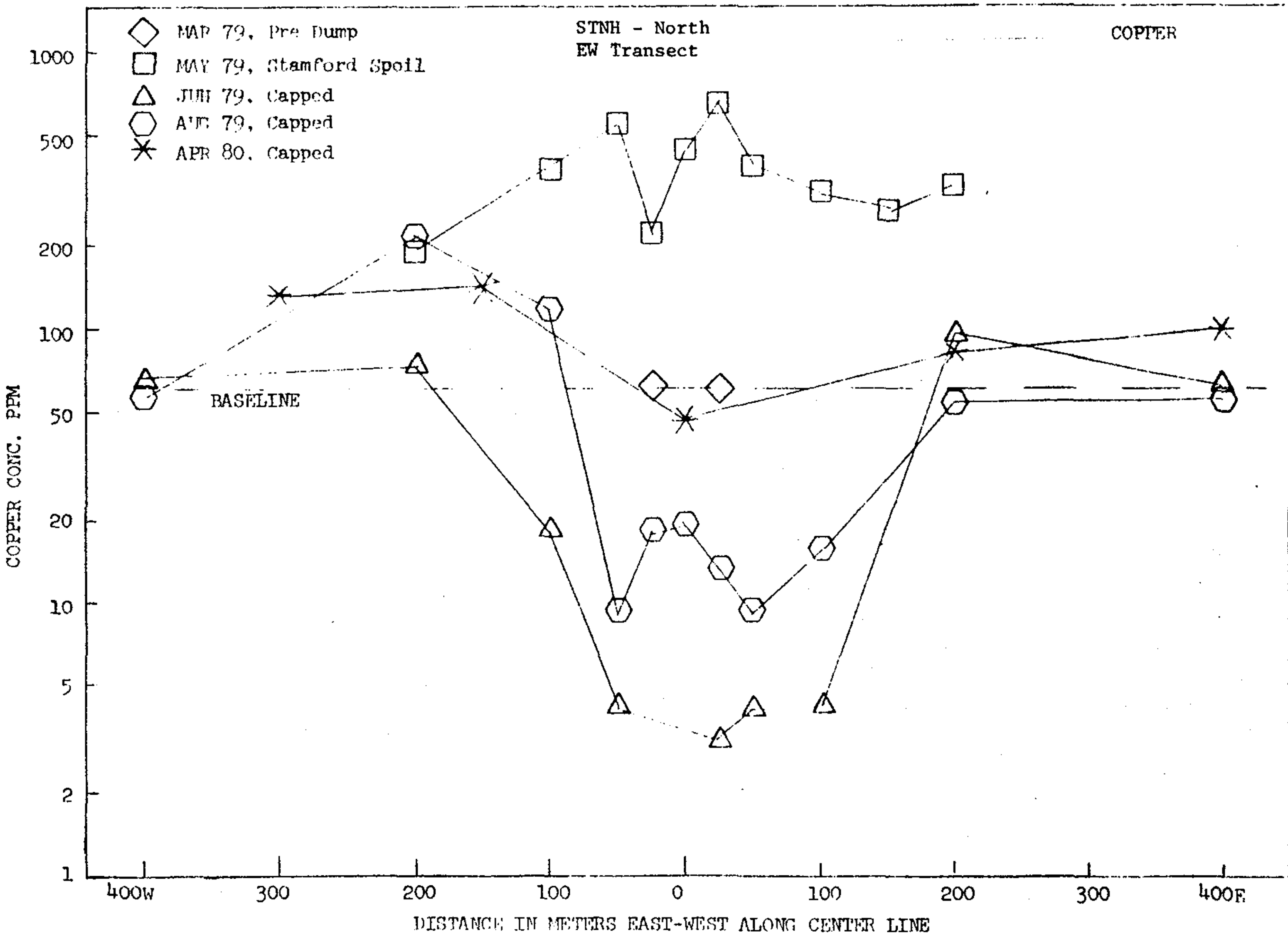
5.4.1-1 Summary of mean Copper (Cu) concentrations at the Stamford-New Haven - North Disposal Site; May, 1979 - April, 1980



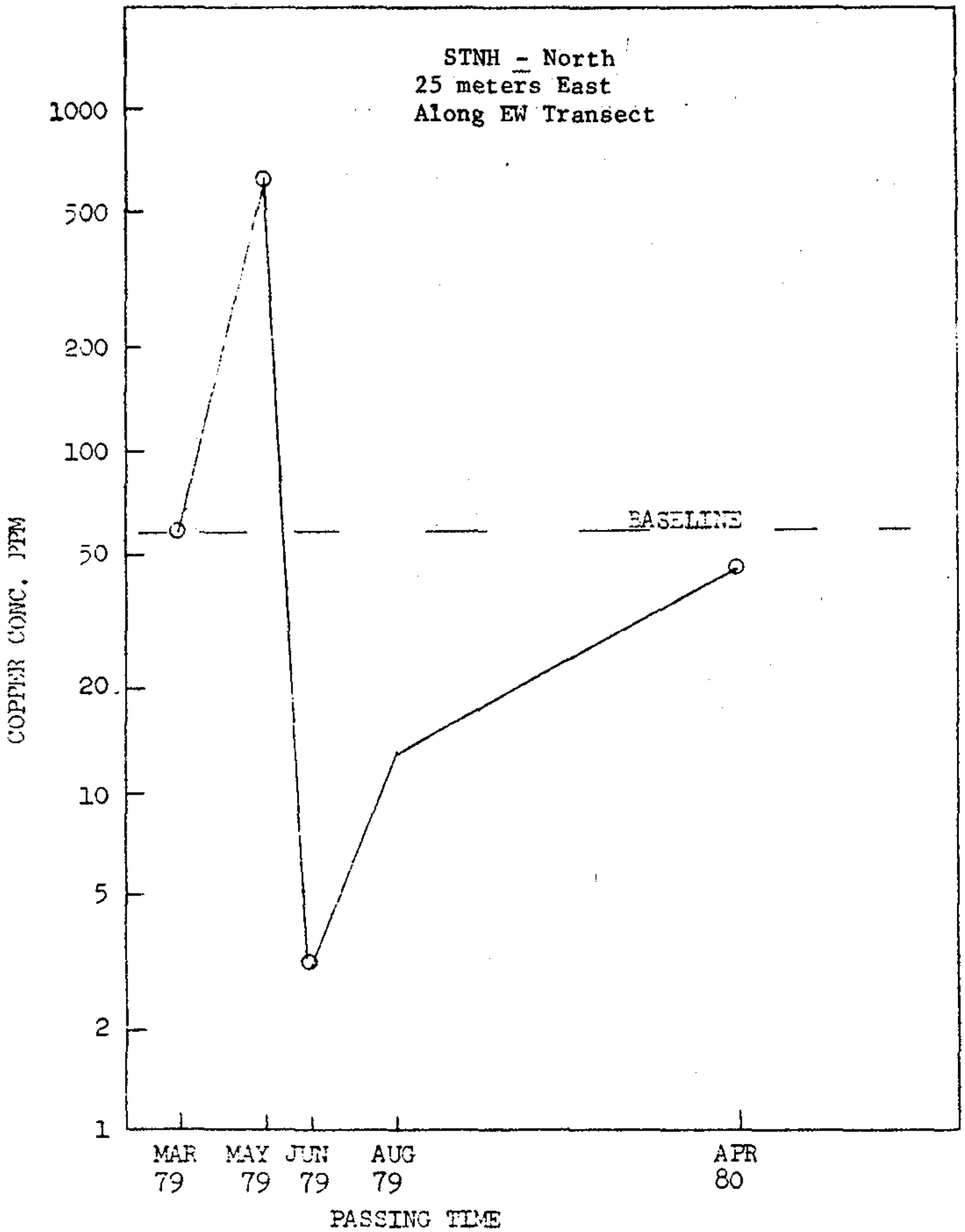
5.4.1-2 Spatial and temporal distribution of Cu data at STNH-North along NS transect



5.4.1-3 Copper concentrations at a station 100 m south along NS transect at the STNH-North Site



5.4.1-4 Spatial and temporal distribution of Cu data at STNH-North along EW transect

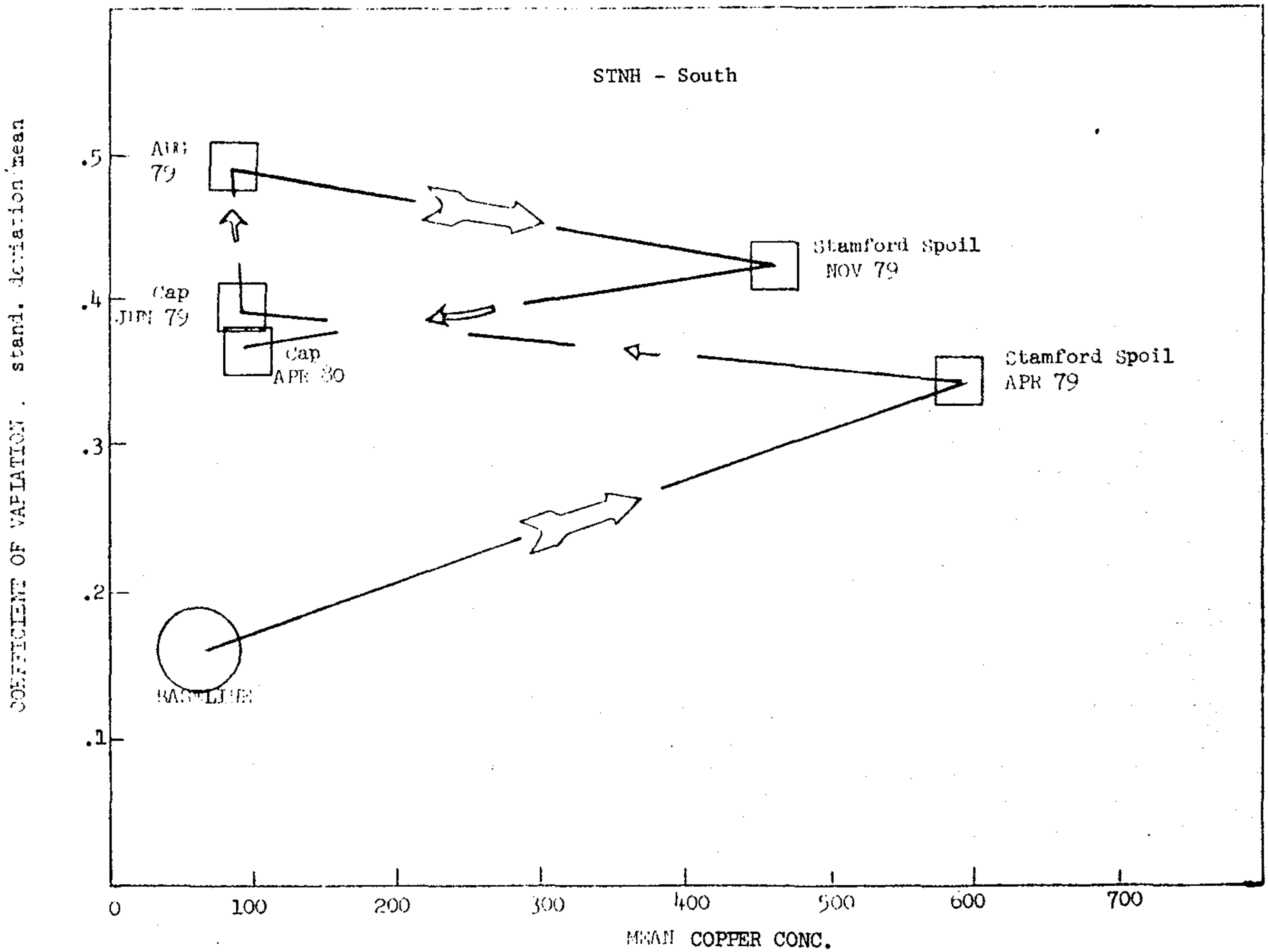


5.4.1-5 Copper concentrations at a station 25 m east along EW transect at the STNH-North Site with the factors controlling sediment distribution.

When Stamford dredged material was placed on the site, both the concentration and variability of the sediment increased drastically. After placement of the sand cap, in June, the concentration of Cu dropped to an extremely low value and although the variability was less than that of Stamford it was still greater than that of natural sediment. Post-disposal monitoring results obtained from the August 1979 survey indicated a slight increase in both copper concentration and sample variability in the surface sediments. April 1980 data indicated that the sediments at the STNH-North disposal pile were approaching both the concentrations and low variability typical of the natural sediments (Figures 5.4.1-2 to 5.4.1-5).

This return to baseline conditions could result from the deposition of natural sediments over the capping material. Further sampling will be required to determine if this is in fact the case. One important characteristic of the data that appears relevent to this, and other areas, is the increase in variability associated with disposal even though the mean concentration levels of metals following capping are initially lower than natural bottom.

Figures 5.4.1-2 and 5.4.1-3 present the spatial and temporal changes in Cu concentration on the NS transect, while Figures 5.4.1-4 and 5.4.1-5 present the same data on the EW transect. In summary, the Cu concentrations on the margins of the disposal site (400 m from the center of the disposal mound) generally remained quite stable and resembled Cu concentrations found in local, pre-disposal sediments (70 ppm). On the disposal mound, the concentration increased drastically with deposition of



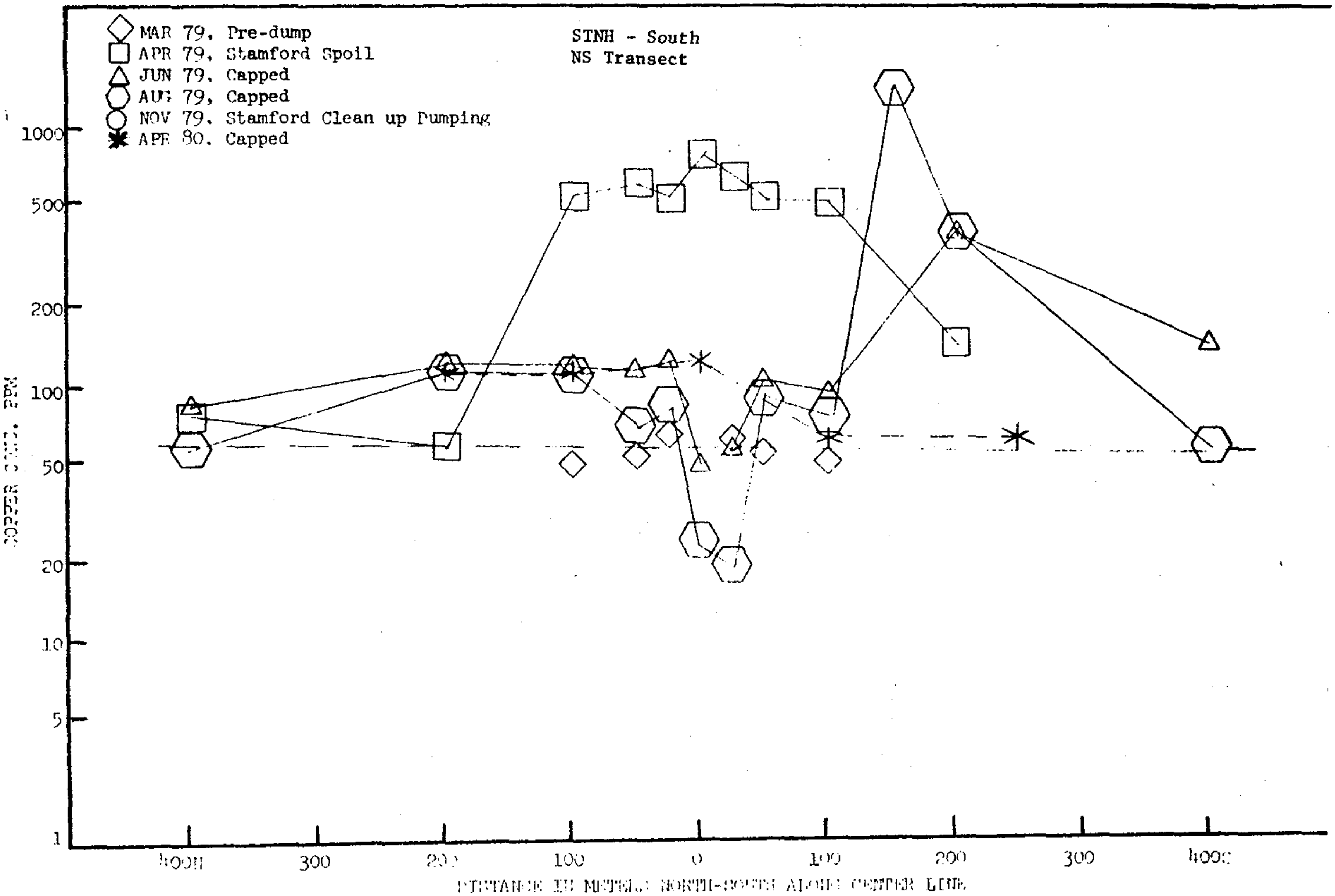
5.4.2-1 **Summary of mean Copper (Cu) concentrations at the STNH-South Disposal Site. May 1979 - April, 1980**

Stamford material to levels of 400-500 ppm. Immediately after placement of the capping material, the levels on the mound decreased by a factor of 100 to 4-5 ppm. During the period following the capping operation the concentrations gradually increased until the levels on the mound were comparable with the baseline. Further sampling will be conducted to determine whether Cu values remain at background levels in the future.

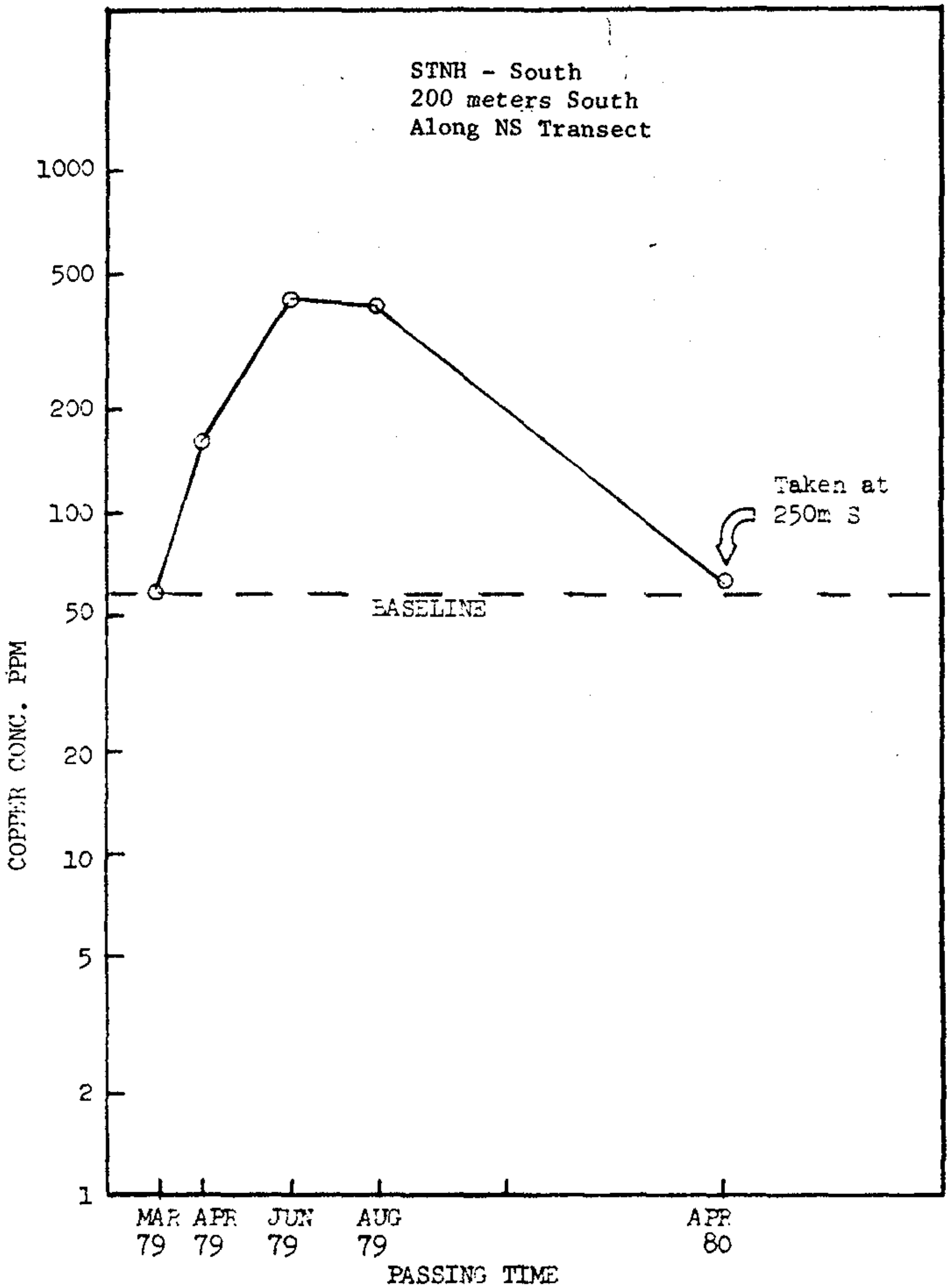
5.4.2 Stamford-New Haven South (STNH-South) Disposal Site

Copper concentrations at the STNH-South site resembled those at STNH-North in terms of fluctuations in response to disposal activity. Analysis of data at the south site is complicated, however, by multiple disposal and capping operations. The pre-disposal baseline survey conducted in March, 1979, found the mean Cu concentration to be approximately 60 ppm with a very low coefficient of variation (Fig. 5.4.2-1). This is consistent with the baseline observations at the North site. Immediately following disposal of the Stamford material, Cu concentrations of approximately 750 ppm were recorded, principally at the center of the site, although elevated concentrations were found 300 m to the east, along the EW transect (Figs. 5.4.2-2 and 4).

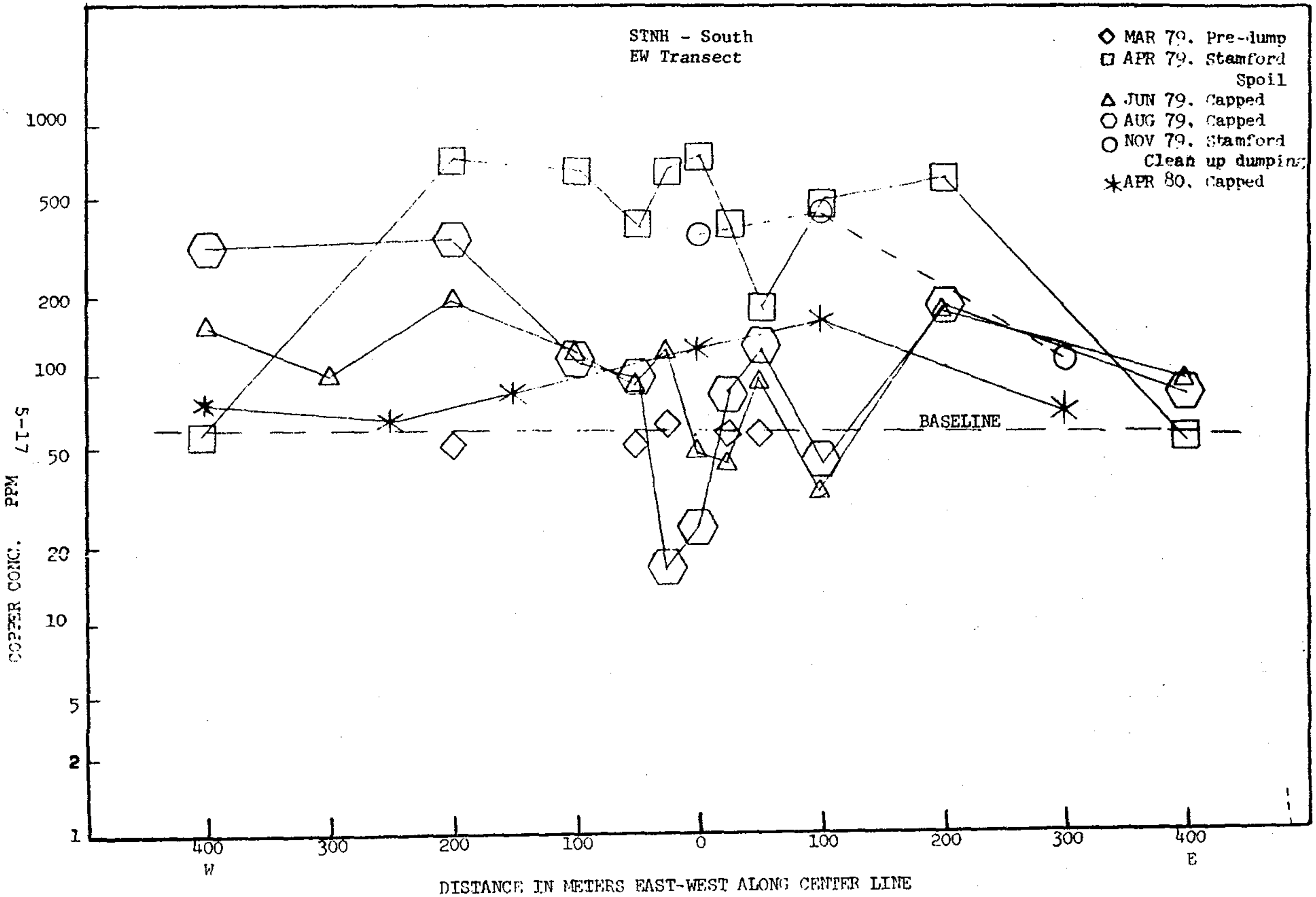
The June, 1979 survey, performed shortly after the Stamford material was capped with New Haven silt, showed that the cap effectively reduced Cu concentrations to levels indicative of New Haven harbor silt. It had been detected bathymetrically, and verified by diver observation, that the capping material was providing inadequate cover and that Stamford dredged material was exposed in some sectors to the east and south of the disposal site. This was reflected in continued elevated Cu concentrations



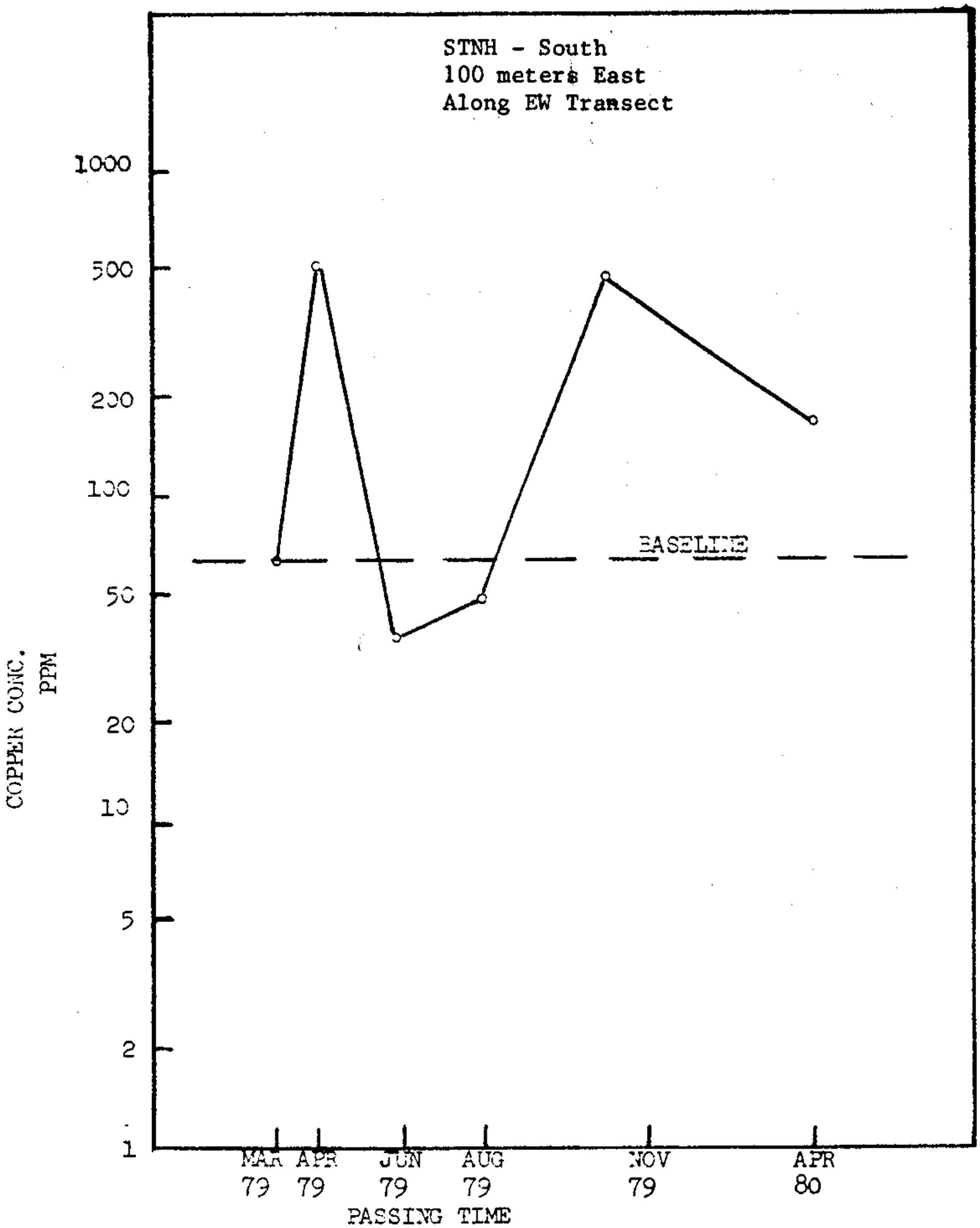
5.4.2-2 Spatial and temporal distribution of Cu data at STNH-South along NS transect



5.4.2-3 Copper concentration at a station 200 m south along NS transect at the STNH-South Site



5.4.2-4 Spatial and temporal distribution of Cu data at STNH-South along EW transect



5.4.2-5 Copper concentrations at a station 100 m E along EW transect at the STNH-South Site

200 m east along the EW transect and 400 m to the south along the NS transect (Figs. 5.4.2-2 and 4). These data are extremely variable, ranging between approximately 75 ppm where the cap was most effective, to 450 ppm at some sites. It should be noted that Cu levels never fell below baseline concentrations at the STNH-South site as they did when sand was deposited at the STNH-North site.

The August, 1979 survey revealed the existence of exposed Stamford material on the west flank which had been previously undetected. The August data, however, are extremely variable, ranging between 20 and 1000 ppm, and should, therefore, be interpreted cautiously.

Additional Stamford material was deposited on the eastern flank of the disposal site in November, 1979. Copper levels of approximately 400 ppm were found 100 m east from the center along the EW transect. These resemble Cu concentrations found at this site following the initial disposal of Stamford material, which ceased in April, 1979 (Figure 5.4.2-4). These samples may reflect the most recent disposal operation.

During March, 1980, additional disposal of New Haven silt was conducted at the STNH-South site. Most of the disposal took place east of the disposal buoy to cover Stamford material deposited diring November, 1979, however, thirty-four scow loads were deposited at specific points at Loran-C control to cover the exposed Stamford material on the south and west flanks of the mound (DAMOS Contribution #12, May 1980). Following the disposal operation, the STNH-South site was visited during April 1980. The results of the April survey indicated a general stabilizing trend in Cu concentration and resembled the results of the June survey (post-cap) most cases.

The sediment chemistry data will be discussed in more detail in subsequent reports as data become available.

5.4.3 New Haven Reference and Baseline

Better statistical analysis became possible after the April, 1980 survey because of the increased number of replicates (10) collected at each station. The larger sampling matrix was adopted in an attempt to decrease biological sample-to-sample variability, and to better correlate biological data with sediment chemistry. Means, standard deviations, and coefficients of variation were calculated for all baseline sediments, capping materials and dredged materials.

The New Haven reference site, as of April 1980, resembled baseline data for the North and South sites. The baseline sediments in the entire New Haven area appear to be rather homogeneous in terms of Cu concentration; the mean Cu concentration at both STNH-North and South (pre-disposal) is approximately 70 ppm with a standard deviation of $\pm$ 15 ppm. With these data as background information, the bulk sediment analysis approach should contribute significantly to monitoring the stability of disposed dredged material in the Central Long Island Sound site.